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FLEET RELIABILITY ASSESSMENT PROGRAM. VOLUME 1. GENERAL PROGRAM--ETC(U)

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FINAL REPORT, VOLUME 1

FLEET RELIABILITY ASSESSMENT PROGRAM

FRAP

NAVAL ELECTRONICS SYSTEMS COMMAND

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GENERAL PROGRAM REPORT

NAVAL WEAPONS SUPPORT CENTER

CRANE, INDIANA

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PAGE NO.	*CHANGE NO.
Title	0
A	0
i to viii	0
1 to 54	0

A

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DEPARTMENT OF THE NAVY

NAVAL ELECTRONICS SYSTEMS COMMAND

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CHANGE NO.	DATE	TITLE OR BRIEF DESCRIPTION	ENTERED BY

FINAL REPORT

TABLE OF CONTENTS

CONTENTS

VOLUME 1 GENERAL PROGRAM REPORT

TABLE OF CONTENTS

Section | Page

LIST OF ILLUSTRATIONS

LIST OF TABLES

VOLUME 1 GENERAL PROGRAM REPORT

SECTION I - INTRODUCTION

1-1 BACKGROUND

The FLEET RELIABILITY ASSESSMENT PROGRAM (FRAP) was created as a result of a top priority Chief of Naval Materiel (CNM) requirement for a fast, reliable, and accurate system of problem identification on new electronic equipment installations aboard ships. FRAP typically monitors a selected sample of an equipment population over a period of six months. The failure data collected from maintenance actions performed during this period is analyzed and reports are generated which identify the problems and recommend corrective actions. The basic goals of the program are to improve operational reliability and to reduce life cycle costs.

An important objective of the program is the quick identification of problems so that corrective actions can be taken early in the equipment life cycle. There are several distinct advantages to this approach:

a. Reliability - Weaknesses in design and/or components which result in failures are more likely to occur during operation in a real service environment. FRAP is designed to detect the equipment faults during the first few months of operation so that steps can be taken quickly to resolve the problems, thus improving the equipment functional reliability within a relatively short time frame.

b. Contractor Liability - Detection of new equipment faults while the warranty provisions are still in effect results in cost savings to the Fleet since the manufacturer remains responsible for re-design, retrofits, and repairs.

c. Cost Avoidance - Costs involved with modifying, or retrofitting equipment can be curtailed through use of the FRAP sampling technique to identify isolated failures that do not effect entire equipment populations.

d. Allowance Parts List - FRAP provides information on the equipment and component failure rates, thus effecting APL quantities and central supply depot stock levels.

e. Data Collection - FRAP assists in reducing or eliminating extraneous or diverse data collection and special reporting requirements while improving the Navy's 3-M system responsiveness.

f. Information Distribution - FRAP publishes and distributes a monthly feedback report to all participants regarding equipment/system status, fixes, proposed corrective actions, and other pertinent information of general interest.

g. Corrective Actions - FRAP informs the Navy Program Manager of problems while the contractor is responsible for the equipment performance and still has design teams organized to resolve the failures. Engineering Change Proposals can be processed more effectively while knowledge of system theory and component structure is recent.

The initial phase of FRAP proved the feasibility of obtaining the desired goals through an organized effort using a controlled sampling technique. The FRAP system assures a rapid response through a coordinated effort of Fleet personnel, naval and contractor facilities, and equipment support activities. The activities involved in this effort are illustrated in Figure 1-1. The results of the pilot phase are available in the FRAP document "FINAL REPORT, FLEET RELIABILITY ASSESSMENT PROGRAM", dated 1 SEPTEMBER 1977 and can be obtained from the Defense Documentation Center at Alexandria, Virginia. A summary of the program and its accomplishments were presented to the 3-M Policy Committee (chaired by OP-43, RADM L. W. Fisher). The members agreed that the program is "beneficial/necessary". The committee authorized continuation and expansion of FRAP to encompass NAVAIRSYSCOM and NAVSEASYSCOM shipboard equipment in addition to that of NAVELEXSYSCOM and requested MAT-04 (RADM S. A. White) to prepare a proposed change to OPNAVINST 4790.4, Volume II (3-M manual) to incorporate the FRAP program.

1-2 PURPOSE

The purpose of this document is to report the results of the FRAP second phase effort. VOLUME 1, GENERAL PROGRAM REPORT, provides the equipment summary reports, a discussion of the FRAP organization, and program modifications. VOLUME 2, EQUIPMENT REPORT, details the reliability, maintainability, and availability of the equipment in the FRAP sample and includes the reliability model of each equipment type.

1-3 SCOPE

This report presents the results of FRAP maintenance data collection and analysis on four types of equipment/systems. The system types and quantities used in the FRAP sample are listed in TABLE 1-1. The types and number of platforms participating in the program are shown in TABLE 1-2. TABLES 1-3 and 1-4 provide a complete listing of the ATLANTIC and PACIFIC FLEET platforms that participated in FRAP.

TABLE 1-1. EQUIPMENT LIST

TYPE DESIGNATION	EQUIPMENT NAME	SAMPLE QUANTITY	TYPE NO.
AN/TPX-42A(V)( )	CATCC-DAIR Interrogator Set	3	1
AN/SYQ-7(V2)	NAVMACS A+ Communication System	19	2
CV-3333/U	Audio Digital Converter	22	3
AN/ON-143(V5)/USG	Interconnecting Group	12	4

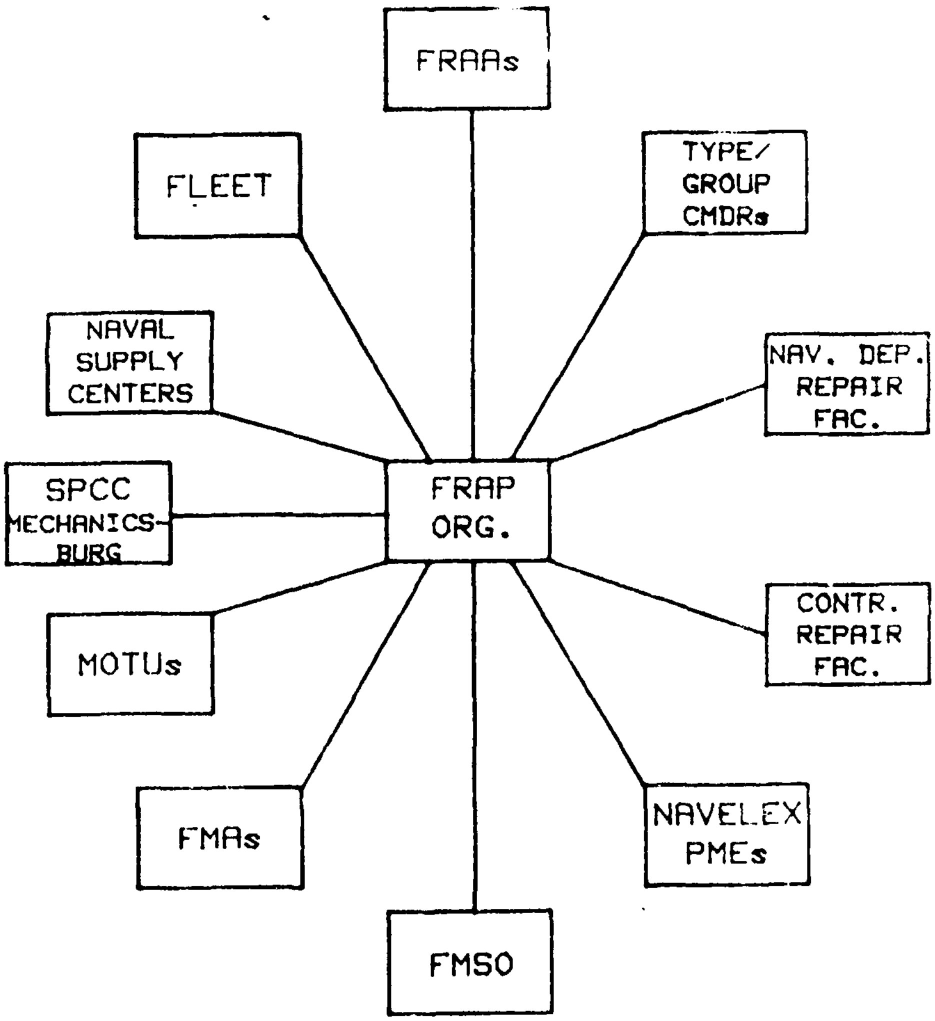

FIGURE 1-1 FRAP INTERFACES

TABLE 1-2. FRAP SHIP SAMPLE TYPES

SHIP TYPE	LANTFLT	PACFLT	TOTAL
CARRIER	3	3	6
DESTROYER	4	1	5
FRIGATE	4	0	4
CRUISER	3	1	4
AUXILLIARY	5	0	5
LANDING SHIP	3	3	6
SUBMARINE	4	11	15
TOTAL	26	19	45

TABLE 1-3. FRAP SAMPLE PLATFORMS (LANTFLT)

PLATFORM NAME	HULL NUMBER	SHIP TYPE
ALBANY	CG-10	GUIDED MISSILE CRUISER
AYLWIN	FF-1081	FRIGATE
BARNEY	DDG-6	GUIDED MISSILE DESTROYER
BLUEFISH	SSN-675	NUCLEAR SUB
BOWEN	FF-1079	FRIGATE
CORONADO	LPD-11	AMPHIBIOUS TRANSPORT
DACE	SSN-607	NUCLEAR SUB
DALE	CG-19	GUIDED MISSILE CRUISER
DEWEY	DDG-45	GUIDED MISSILE DESTROYER
EISENHOWER	CVN-69	NUCLEAR AIRCRAFT CARRIER
GLOVER	AGFF-1	RESEARCH FRIGATE
GUAM	LPH-9	AMPHIBIOUS ASSAULT SHIP
INCHON	LPH-12	AMPHIBIOUS ASSAULT SHIP
INDEPENDENCE	CV-62	AIRCRAFT CARRIER
JACK	SSN-605	NUCLEAR SUBMARINE
LUCE	DDG-38	GUIDED MISSILE DESTROYER
MULLINNIX	DD-944	DESTROYER
PUGET SOUND	AD-38	DESTROYER TENDER
SANTA BARBARA	AE-28	AMMUNITION SHIP
SARATOGA	CV-60	AIRCRAFT CARRIER
TINOSA	SSN-606	NUCLEAR SUBMARINE
TRIPPE	FF-1075	FRIGATE
VREELAND	FF-1068	FRIGATE
VULCAN	AR-5	REPAIR SHIP
YARNELL (HARRY E.)	CG-17	GUIDED MISSILE CRUISER
YOSEMITE	AD-19	DESTROYER TENDER

TABLE 1-4. FRAP SAMPLE PLATFORMS (PACFLT)

PLATFORM NAME	HULL NUMBER	SHIP TYPE
BLUE RIDGE	LCC-19	AMPHIBIOUS COMMAND SHIP
CONSTELLATION	CVA-64	ATTACK AIRCRAFT CARRIER
DRUM	SSN-677	NUCLEAR SUBMARINE
FLASHER	SSN-613	NUCLEAR SUBMARINE
GUARDFISH	SSN-612	NUCLEAR SUBMARINE
GURNARD	SSN-662	NUCLEAR SUBMARINE
HADDO	SSN-604	NUCLEAR SUBMARINE
HAWKBILL	SSN-666	NUCLEAR SUBMARINE
KINKAID	DD-965	DESTROYER
KITTY HAWK	CV-63	AIRCRAFT CARRIER
LEAHY	CG-16	GUIDED MISSILE CRUISER
NEW ORLEANS	LPH-11	AMPHIBIOUS ASSAULT SHIP
OKINAWA	LPH-3	AMPHIBIOUS ASSAULT SHIP
PINTADO	SSN-672	NUCLEAR SUBMARINE
POGY	SSN-647	NUCLEAR SUBMARINE
POLLACK	SSN-603	NUCLEAR SUBMARINE
QUEENFISH	SSN-651	NUCLEAR SUBMARINE
RANGER	CV-61	AIRCRAFT CARRIER
SEADRAGON	SSN-584	NUCLEAR SUBMARINE

SECTION II - RESULTS SUMMARY

2-1 CATCC-DAIR

2-1.1 INTRODUCTION

The Carrier Air Traffic Control Center-Direct Altitude and Identity Readout (CATCC-DAIR) is a shipboard aircraft identification and coordination system used for air traffic control and support of flight operations within a fifty mile radius of the ship. The system is essential to the safety and combat readiness of the ship which requires the system to be operational at all times while the ship is underway.

The CATCC-DAIR consists of a programmable Interrogator Set AN/TPX-42A(V)8 utilizing the AN/UYK-20(V) electronic digital mini-computer. Enhanced reliability is obtained by installing a second AN/UYK-20(V) in a parallel redundant scheme. All of the systems in the FRAP study were so configured.

2-1.2 SUMMARY

Only three CATCC-DAIR systems were studied by FRAP. However, by extending the data collection period to nine months, sufficient data was obtained to enable statistical calculations with meaningful confidence. Based on analysis of data received from the Fleet and from FMSO, the following is concluded:

(1). The equipment reliability required by ELEX-I-198 is not being met in Fleet operation. The specification, which is based on an exponential failure distribution, requires a mean-time-to-failure of 700 hours, which is equivalent to a median-time-to-failure of 485 hours. The observed failure distribution, being Weibull, is best compared with the specification by comparing medians. The median of the observed failure distribution was only 126 hours — considerably less than the specified 485 hours.

(2). Operational reliability of the system was very good, with no failures observed that reduced the system capability by more than 10 percent. NOTE: The most frequent failure was the deflection amplifier in one of the five Control Group PPI Consoles.

(3). The maintainability (repair time) requirement is not being met. Specification ELEX-I-198 requires a Mean Time To Repair of 0.75 hours, whereas a MTTR of 18 hours was observed.

(4). Effective availability is very good because of the redundancy in the system design.

Table 2-1 summarizes the reliability, maintainability, and availability analyses. NOTE: Although 3 ships participated in the FRAP data collection, data from one of the ships is considered to bias the statistics because of the fact the CATCC-DAIR system aboard this ship was never fully operational. Therefore, only the data from the remaining two ships is summarized here; however, the complete data analysis is presented in Volume 2 of this report.

LEGEND

1. All Data = All Collected Data (Failures/Maintenance Actions)**
2. EQUIP = EQUIPMENT **
3. PARTS = PARTS REPLACEMENT **
4. EXP = EXPONENTIAL
5. LN = LOGNORMAL

TABLE 2-1. DATA SUMMARY FOR CATCC-DAIR.

PARAMETER	All Data	EQUIP	PARTS
OPERATIONAL			
Calendar Hours	11,616	11,616	11,616
Operating Hours	5073	5073	5073
Duty Cycle	0.437	0.437	0.437
Sample Size	2*	2*	2*
RELIABILITY			
Number of Failures	12	10	9
Time Between Failures-Mean	661	971	1304
Time Between Failures-Median	111	126	111
Distribution	WEIBULL	WEIBULL	WEIBULL
MAINTAINABILITY			
Total Repair Time	126	110	110
Number of Repairs	7	6	8
Time to Repair-Mean	18	18.3	17.5
Time to Repair-Median	5.3	4.4	4.6
Distribution	LN	LN	LN
Total Down Time	1132	772	783
Repairs (or Maint. Act.)	7	6	8
Down Time-Mean	162	129	102
Down Time-Median	112	89	46
Distribution	EXP	EXP	WEIBULL
AVAILABILITY			
Inherent	0.9734	0.9815	0.9868
Observed-Mean	---	0.525	---
Observed-Median	---	0.577	---
Effective	0.9996	---	---

*CATCC-DAIR SUMMARY Does Not Include USS INDEPENDENCE Data.

**Reference Volume 1, Paragraph 3-4, and Volume 2A, Paragraph 7-2

NOTE: All Time Units Are in Hours

2-1.3 REMARKS

In addition to hardware problems, FRAP has received comments from Fleet users regarding human interface inconveniences and software problems. The comments from the users of the "Human Engineered" keyboard in the OD-58 consoles were strongly negative. The keyboard is laid out in a sequential alphabetic "ABC" order from the upper left-hand corner which makes touch typing practically impossible and forces operators to "hunt and peck". The design builds an inherent safety hazard into air traffic control because of slower typing speed and reduced operator accuracy.

Software problems encountered in the early phases of the sample period are being resolved by replacing the interim software with a "fourth generation" package currently under development.

2-2 NAVMACS A+

2-2.1 INTRODUCTION

The NAVAL MODULAR AUTOMATED COMMUNICATION SYSTEM (NAVMACS) A+ is an automated message handling telecommunications system capable of operating ship-to-shore via high frequency (2-30 MHz) independent sideband receivers and a two-way SATCOM link. The system is the primary link between deployed surface platforms and the world-wide Naval telecommunications network. NAVMACS is designed to differentiate incoming traffic for messages addressed to the ship, which are stored and printed in full, and those not addressed to the ship. The record of the latter messages is maintained by printing the address headers, time, and date.

NAVMACS consists of the following ten modules of which nine are unique: (1) Data Processing Set AN/UYK-20(V); (2) Interconnecting Group OJ-143(V)/USQ; (3) Converter/Patch Panel CV-3022/UG; (4) Line Printer TT-624(V)/UG (2 units); (5) Cassette Magnetic Tape Unit RD-396(V)/U; (6) High Speed Paper Tape Reader/punch RD-397/U; (7) Teletype Reperforator TT-192C; (8) Teletype Transmit Distributor (TD) TT-187/UG; and (9) Teletypewriter Set AN/UGC-20A (or B).

2-2.2 SUMMARY

The FRAP sample of NAVMACS included nineteen (19) systems. Although no system level specifications exist for the NAVMACS A+, it is concluded that the system meets or exceeds a guide specification derived from an estimate of the individual equipment specifications, MIL-HDBK-217B, and engineering estimates. Table 2-2 summarizes the reliability, maintainability, and availability analyses.

2-2.3 REMARKS

FRAP analysis of the paper feed roller on the TT-624 printer has revealed that the center section of the roller has undergone significantly more oxidation aging than have the end sections. It is beleived that failure of the center section is the result of this aging. Inspection of the chemical extracts indicates significantly less carbon black

LEGEND

1. OPER. = OPERATIONAL *
2. EQUIP. = EQUIPMENT *
3. PARTS = PARTS REPLACEMENT *

TABLE 2-2 . DATA SUMMARY FOR NAVMACS A+.

PARAMETER	OPER	EQUIP	PARTS
OPERATIONAL			
Calendar Hours	95,736	95,736	95,736
Operating Hours	53,272	53,272	53,272
Duty Cycle	0.556	0.556	0.556
Sample Size	19	19	19
RELIABILITY			
Number of Failures	21	26	23
Time Between Failures-Mean	2421.5	4048.9	2219.7
Time Between Failures-Median	1678.4	1420.2	1538.6
Distribution	EXP	EXP	EXP
MAINTAINABILITY			
Total Repair Time	44	41	110
Number of Repairs	13	11	20
Time to Repair-Mean	3.38	3.7	5.5
Time to Repair-Median	2.35	2.6	3.81
Distribution	EXP	EXP	EXP
Total Down Time	5141	5307	4901
Repairs (or Maint. Act.)	13	11	20
Down Time-Mean	395.5	482.5	245.0
Down Time-Median	35.8	43.6	20.5
Distribution	LN	LN	LN
AVAILABILITY			
Inherent	0.9986	0.9982	0.9975
Observed-Mean	0.8505	0.8194	---
Observed-Median	0.9732	0.9632	---
Effective	0.9119	0.9094	0.9158

* Reference Volume 1, Paragraph 3-4
NOTE: All Time Units Are In Hours

content in the center section than the end sections. Carbon black is added to rubber to retard oxidation aging and it is believed that the life of the center section can be extended by increasing the amount of carbon black added during manufacture of the rubber or by using a type of rubber which has a higher carbon content.

Samples of the types of paper used in the printer were analyzed for acid content. The results indicated a ph of 4.4 for yellow pulp, 4.5 for white bond, and 4.9 for white pulp. However, the acid content of the paper is not damaging to the rubber roller and would, in fact, retard the oxidation aging.

A solution was suggested for resolving the paper feed problem. This was to install a pin drive tractor feed and use edge perforated paper in place of the regular TTY paper.

Other reports concerning the printer were directed toward problems with the ribbon. One common report was the failure of the ribbon reversing mechanism which resulted in lost message traffic. Another report mentioned that the ribbons billow as they become aged and can rub or catch on the rotating print drum.

Another reported problem was with the RD-397 air filter which was picking up chaff from the paper tape resulting in overheating if not cleaned daily.

2-3 CV-3333

2-3.1 INTRODUCTION

The CV-3333/U AUDIO-DIGITAL CONVERTER (VOCODER) is a digital voice analyzer-data converter providing digitized speech output at 2400 baud (bits per second). The unit processes and converts voice inputs into a serial bit stream which can be encrypted and combined with other data streams for transmission. The system is an integral part of the Shipboard Fleet Satellite Communications Narrow Band Secure Voice System. The Narrow Band Secure Voice system provides long range ship-to-shore communications on a shared channel basis.

The CV-3333/U is used with the ON-143(V) Interconnecting Group and the KG-36-4 Cryptographic machine to produce the encyphered bit stream which is then transmitted by the AN/WSC-3 Satellite Communications Set.

The CV-3333/U is a single unit requiring only power and hook-ups to communications channels for operation.

2-3.2 SUMMARY

The number of CV-3333/U systems in the FRAP sample was 22. The data collected and analyzed on the system resulted in the conclusion that no significant operational problems exist with the CV-3333 and that the unit meets or exceeds the specification requirements as defined in the production contract. Table 2-3 summarizes the reliability, maintainability, and availability analyses.

LEGEND

1. OPER - OPERATIONAL *
2. EQUIP - EQUIPMENT *
3. PARTS - PARTS REPLACEMENT *

TABLE 2-3 . DATA SUMMARY FOR CV-3333 .

PARAMETER	OPER	EQUIP	PARTS
OPERATIONAL			
Calendar Hours	111,624	111,624	111,624
Operating Hours	47,677	47,677	47,677
Duty Cycle	0.427	0.427	0.427
Sample Size	22	22	22
RELIABILITY			
Number of Failures	2	1	1
Time Between Failures-Mean	23,838	47,677	47,677
Time Between Failures-Median	16,524	33,040	33,040
Distribution	---	---	---
MAINTAINABILITY			
Total Repair Time	33	13	13
Number of Repairs	2	1	1
Time to Repair-Mean	16.5	13	13
Time to Repair-Median	---	---	---
Distribution	---	---	---
Total Down Time	240	168	168
Repairs (or Maint. Act.)	---	---	---
Down Time-Mean	120	168	168
Down Time-Median	---	---	---
Distribution	---	---	---
AVAILABILITY			
Inherent	0.9993	0.9997	0.9997
Observed-Mean	---	---	---
Observed-Median	---	---	---
Effective	0.9949	0.9965	0.9965

* Reference Volume 1, Paragraph 3-4
NOTE: All Time Units Are In Hours

2-3.3 REMARKS

To obtain running time data, FRAP was required to install outboard Elapsed Time Meters (ETM) on the CV-3333. It is recommended that future procurements include ETMs.

2-4 ON-143(V)5

2-4.1 INTRODUCTION

The ON-143(V)5/USQ Interconnecting Group (IG) is an electronic interface and control device within the AN/USQ-64(V)3 Communications Systems Control Central. The unit performs six major system functions: (1) Signal Interfacing; (2) Sequencing of System Equipments; (3) Link Control; (4) Message Processing; (5) Vocoder Interface; and (6) Monitoring and Alarm Indication. The ON-143(V)5 serves as an interface and sequence control for the Input/Output devices, crypto, voice digitizer (AN/CV-3333/U) and the AN/TWS-3 Transceiver. The unit also contains the Submarine Satellite Information Exchange System (SSIXS) operating program.

2-4.2 SUMMARY

A quantity of 12 ON-143(V)5/USQ systems were subjected to the FRAP study. The results of the study indicates that the ON-143(V) meets or exceeds the specification requirements. Table 2-4 summarizes the FRAP reliability, maintainability, and availability analyses.

2-4.3 REMARKS

As illustrated by the summary, the ON-143(V) developed few hardware problems. However, a complaint with Baud Rate for voice communications has been reported frequently. The SSIXS subscribers have been unable to establish voice communications following an ON-143(V) power-up because the ON-143(V) initializes itself at 4800 baud while the Vocoder is at 2400 baud. The stable-base clock in the ON-143(V) can be reset to 2400 baud by switching the system to the DATA mode and executing a RCV, XMT, or CLB command, providing that the strap options are set to 2400 baud. A more permanent solution to the problem is suggested which requires the re-programming of the SSIXS operating program to cause the stable-base clock to initialize at 2400 baud.

LEGEND

1. OPER - OPERATIONAL*
2. EQUIP - EQUIPMENT*
3. PARTS - PARTS REPLACEMENT *

TABLE 2-4. DATA SUMMARY FOR ON-143(V)5.

PARAMETER	OPER	EQUIP	PARTS
OPERATIONAL			
Calendar Hours	60,792	60,792	60,792
Operating Hours	16,173	16,173	16,173
Duty Cycle	0.266	0.266	0.266
Sample Size	12	12	12
RELIABILITY			
Number of Failures	1	1	1
Time Between Failures-Mean	16,173	16,173	16,173
Time Between Failures-Median	11,210	11,210	11,210
Distribution	---	---	---
MAINTAINABILITY			
Total Repair Time	3	3	3
Number of Repairs	1	1	1
Time to Repair-Mean	3	3	3
Time to Repair-Median	---	---	---
Distribution	---	---	---
Total Down Time	72	72	72
Repairs (or Maint. Act.)	1	1	1
Down Time-Mean	72	72	72
Down Time-Median	---	---	---
Distribution	---	---	---
AVAILABILITY			
Inherent	0.9998	0.9998	0.9998
Observed-Mean	---	---	---
Observed-Median	---	---	---
Effective	0.9955	0.9955	0.9955

*Reference Volume 1, Paragraph 3-4
NOTE: All Time Units Are In Hours

SECTION III PROGRAM MANAGEMENT

3-1 FRAP ORGANIZATION

The FRAP organizational structure consists of a sponsor, a Lead Field Activity (LFA), Technical Support Activities (TSA), and Data Collection Activities (DCA) as illustrated in Figure 3-1. The NAVAL ELECTRONICS SYSTEM COMMAND (NAVELEX 470) is the FRAP sponsor and provides general direction and guidance to the LFA. The NAVAL WEAPONS SUPPORT CENTER (NAVWPNSUPPCEN) Crane, Indiana is the LFA responsible to NAVELEX 470 for FRAP management.

3-1.1 DATA COLLECTION ACTIVITIES

The DCAs serve as a single-point-of-contact interface for the Fleet. The DCA responsibilities include receipt of failure reports (OPNAV 4790/2K maintenance action forms, or other) and throwaway parts, entry of the maintenance action information into the data collection system, and forwarding the failed parts to the Technical Support Activities. The DCA is also responsible for introducing and explaining the FRAP procedures to platforms which are initializing sampled equipment for the first time.

3-1.2 TECHNICAL SUPPORT ACTIVITIES

A strong technical knowledge of the assigned equipment enables the TSAs to evaluate and interpret the failure reports received from the DCAs and the depot repair facilities, to analyze failed parts, to determine corrective actions, and to eliminate errors form the data collection system. The TSAs translate the OPNAV 4790/2K maintenance information into machine readable number code format which allows faster, more accurate, data handling and analysis. Upon completion of this process, the coded data is forwarded to the LFA for analysis and reporting.

3-1.3 LEAD FIELD ACTIVITY

The LFA bears the primary responsibility for the management of FRAP which includes the following areas.

(a). Program management and technical direction - The LFA defines the responsibilities of the Data Collection and Technical Support Activities and provides technical support and guidance in the conduct of FRAP.

(b). Equipment functional modeling - The LFA develops reliability models of assigned equipment to determine system degradation based on failure data.

(c). Statistical sampling plans - The LFA determines confidence levels of equipment reliability based on statistical analysis of failure data.

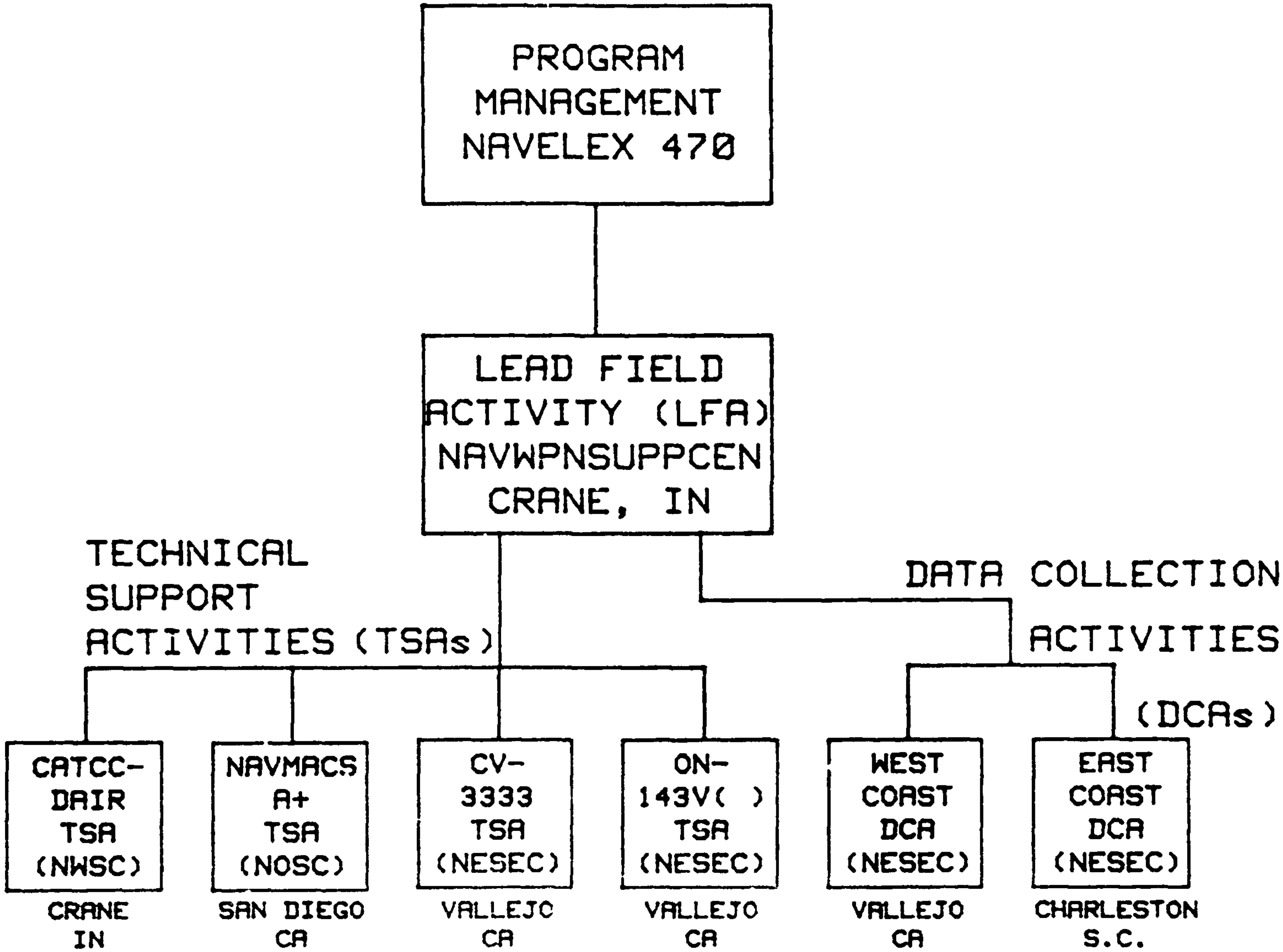

FIGURE 3-1 FRAP ORGANIZATION

(d). Data collection and analysis - The LFA determines data processing equipment requirements and develops software/software procedures for accomplishment of FRAP objectives.

(e). Corrective actions proposals (ECPs, training, etc.)

(f). Engineering R/M/A - Reliability, Maintainability, and Availability assessment of equipment performance.

(g). Failure mode diagnosis and effects analysis.

(h). Reports - The LFA is responsible for the preparation of complete documentation representing the results of collection and analysis of equipment maintenance actions during the nominal six month monitoring period.

3-2 DATA COLLECTION PROCESS

Since the approach to equipment design varies according to the designer and/or manufacturer, the adequacy of a design cannot be fully tested until the equipment is placed in a real service environment. The equipment performance record, in terms of frequency of failure and reasons for failure, describes a historical profile of operational reliability. Such profiles are used to determine future design criteria for prospective systems or to provide supportive evidence for necessary modifications to existing systems. The profiles are also used to define parts provisioning and stock levels for existing systems and to allocate manpower for maintenance and maintenace support functions.

The information describing the effectiveness of systems/equipment in the 3-M system is obtained from the OPNAV 4790/2K Maintenance Action Form (MAF) shown in Figure 3-2. FRAP is supplemental to 3-M and also uses this form to minimize the reporting burden on Fleet personnel. The reporting requirements are shown in Figure 3-3 for both the 3-M MDS and FRAP. As shown, the FRAP requirement includes three types of 2K reports not used by 3-M; INITIALIZATION, FAILURE-FREE-TIME, and TERMINATION. These additional reports are necessary because of the brief time frame of the FRAP sample. The INITIALIZATION report (INIT) establishes the initial conditions at turn-on of a new installation, e.g., the Elapsed Time Meter reading (ETM), type of equipment, serial numbers, date of initialization, etc. The DCAs are responsible for presenting the FRAP reporting procedures to platforms initializing equipment for the first time. The Failure-Free-Time report (FFT) provides data pertinent to duty cycle by tracking ETMs on a monthly basis. Termination reports (TERM) are submitted at the end of the sample period and record the final ETM reading and date of reading.

3-2.1 COMPUTER OPERATIONS

To facilitate the flow of maintenance information, the FRAP program utilizes the CDC CYBERNET computer system to achieve immediate access for data entry and retrieval. CYBERNET is a nationwide time-share computer network which is accessible from nearly any location via local telephone and an acoustically coupled computer terminal from 149 CONUS and 19 foreign cities. This service provides a greatly improved processing time for FRAP data collection. The LFA is responsible for operating the data distribution program which passes the collected data onward from each activity. Once received by the LFA, the data is analyzed and stored in the computer system. These storage areas are referred to as databases and are accessible to all FRAP participants via computer programs.

Figure 3-4 illustrates the FRAP system of processing the raw 2K maintenance action information as received from the participating platforms. The Data Collection Activities, which are established on the East and West coasts, are responsible for entering the maintenance data and equipment type numbers into the collection system. This entry is accomplished by a computer program, called DCA, specifically designed for the data entry function. The program assigns a serial number to each 2K entry for identification purposes, then places the form in a

OPNAV 4790/2K (Rev 6-73) **SHIP'S MAINTENANCE ACTION FORM (2-KILO)** COMP DEFL

SECTION I IDENTIFICATION

JOB CONTROL NUMBER

1. SHIP'S UIC | 2. WORK CENTER | 3. JOB SEQ. NO. | 4. APL/AEL

A. SHIP'S NAME | 5. EQUIPMENT NOUN NAME | 6. W N D | 7. S T A | 8. R C A S | 9. D F N | 10. | 11. | 12.

B. HULL NUMBER | 13. IDENT/EQUIPMENT SERIAL NUMBER | 14. EIC

15. SAFETY HAZARD | 16. LOCATION (*Compartment/Deck/Frame/Side*) | 17. WHEN DISC. DATE YR. DAY

CONFIGURATION CHANGE | FOR INSURV USE

18. ALTERATIONS (*SHIPALT, ORDALT, Fld Chg, etc.*) | 19. ★/★★ | 20. INSURV NUMBER | 21. SUFFIX | 22. | 23. | 24.

SECTION II. DEFERRAL ACTION

25. S/F MHRS. EXP. | 26. DEFER DATE YR. DAY | 27. S/F MHRS REM. | 28. DEADLINE DATE YR. DAY

SECTION III. COMPLETED ACTION

FOR SELECTED EQUIPMENTS ONLY

29. ACT. TKN. | 30. S/F MHRS | 31. COMPLETION DATE YR. DAY | 32. ACT MAINT TIME | 33. TI | 34. METER READING

SECTION IV. REMARKS/DESCRIPTION

35. REMARKS/DESCRIPTION

CONT SHEET

37. CSMP SUMMARY

38. FIRST CONTACT MAINT. MAN (*Print*) | 39. RATE | 40. SECOND CONTACT/SUPERVISOR (*Print*) | 41. PRI | 42. T/A | 43. ... DATE ...

C. DIV. INIT. | D. DEPT. INIT. | E. COMMANDING OFFICER'S SIGNATURE | F. TYCOM AUTHORIZATION

46. SPECIAL PURPOSE | A. | B. | C. | D. | E. | F. | G. | H. | J. | K.

SECTION V. SUPPLEMENTARY INFORMATION

47. BLUEPRINTS, TECH. MANUALS, DWGS, ETC. | AVAILABLE ON BOARD YES NO | 48. PREARRIVAL/ARRIVAL CONFERENCE ACTION REMARKS

SECTION VI. REPAIR ACTIVITY PLANNING/ACTION

49. REPAIR W/C | 50. EST. MHRS. | 51. ASST. REPAIR W/C | 52. ASST. EST. MHRS. | 53. SCHED. START DATE YR. DAY | 54. SCHED. COMP. DATE YR. DAY

55. REPAIR ACTIVITY UIC | 56. WORK REQ. ROUTINE | 57. EST. MANDAYS | 58. EST. MANDAY COST $ | 59. EST. MATERIAL COST $

60. EST. TOTAL COST $ | 61. JOB ORDER NUMBER | 62. LEAD/ISE CODE | 63. DATE OF EST. YR. DAY

64. FINAL ACT. | 65. MHRS. EXPENDED | 66. DATE COMPLETED YR. DAY | G. COMPLETED BY (*Signature - Rate*) | H. ACCEPTED BY (*Signature - Rate/Rank*)

FIGURE 3-2. OPNAV 4790/2K FORM

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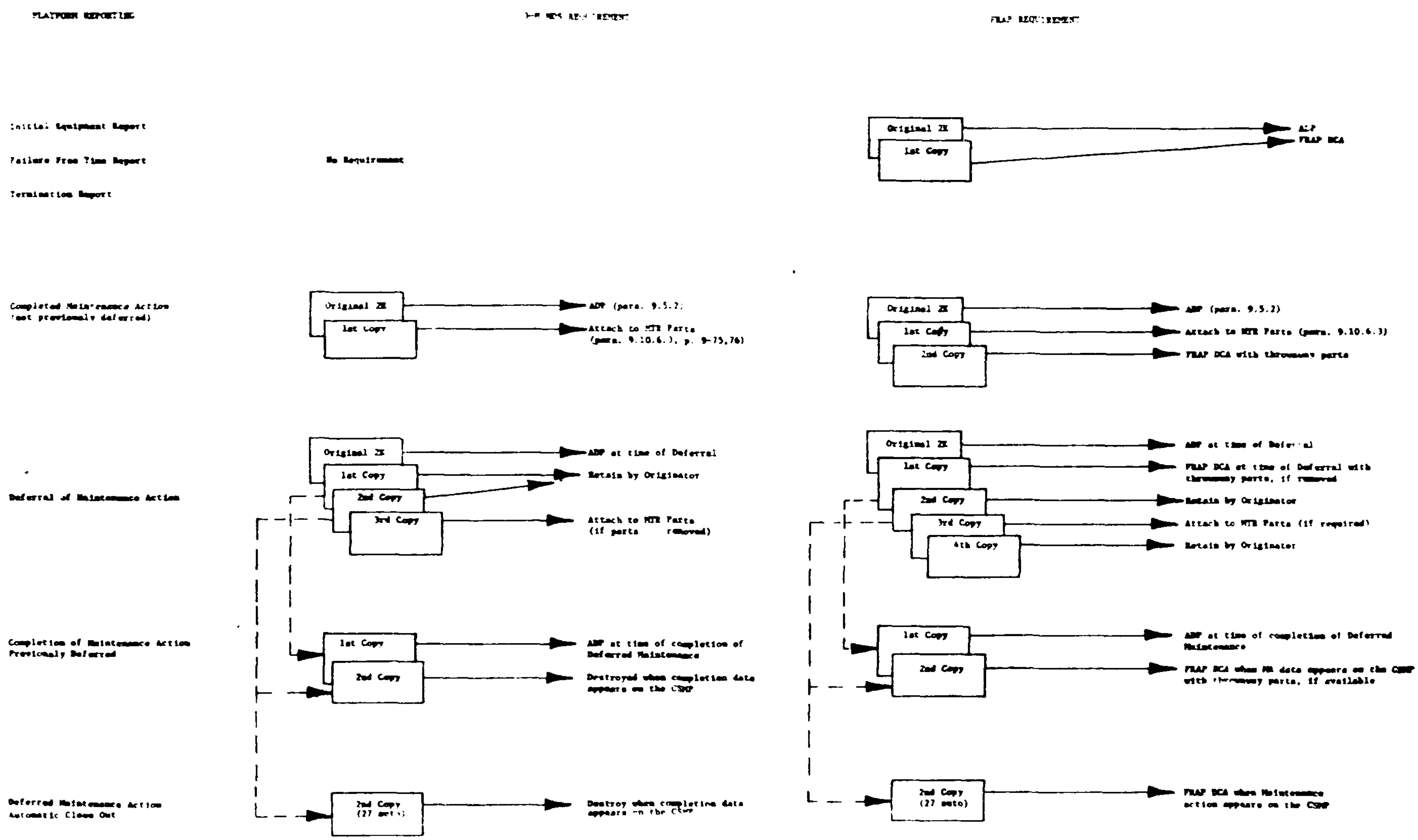

FIGURE 3-3. Types of Reports from the Fleet

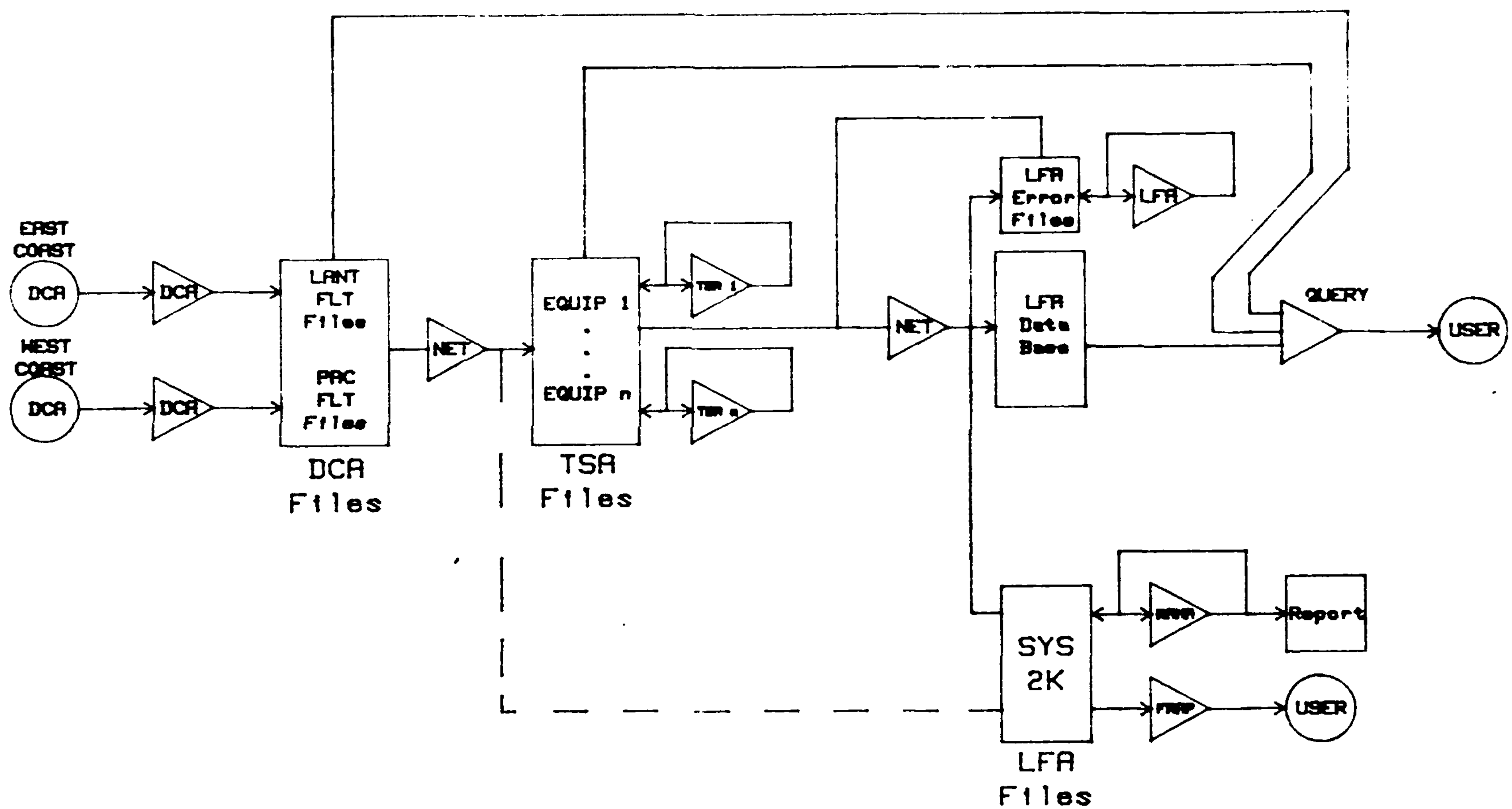

FIGURE 3-4 FRAP DATABASE NETWORK

DCA "mailbox" file. The Lead Field Activity periodically operates a network program, NET, which transfers the contents of the DCA files to the Technical Support Activity files. The equipment type number entered by the DCA determines the TSA routing, i.e., the TSAs receive their respective 2K data as determined by equipment type.

The TSAs review the 2K data to eliminate errors and redundancy then code additional data and place it back into the files for pick up by the LFA. The same network routine used to forward the DCA entries collects the TSA information for the LFA. Once received by the LFA, the data is checked for errors, corrected, and placed into the databases.

The significant computer programs used in the data collection process are described in Appendix A.

3-2.2. DATABASE DEFINITION and PURPOSE

A database is an organized collection of information which is related and categorized. The FRAP databases are defined as the information relating to the maintenance actions performed on new electronic equipment installations aboard ships. The data is obtained in the data collection cycle from the raw 2K maintenance information entered by the DCA, translation to machine readable numeric code at the TSA, and finally, LFA processed data. The databases are designed to accommodate user access for retrieval of the maintenance data, typically in report form. This access allows FRAP team members to review the results of both their individual and combined efforts. Paragraph 3-5, REPORTS, more thoroughly explains the database operations and contents.

3-3 ERROR DETECTION AND CORRECTION

The FRAP method of detecting and eliminating erroneous data combines human and machine processes which are performed at each level of activity, as described in the following paragraphs.

3-3.1 DCA

The DCA is responsible for visually checking the Fleet submitted 2K reports for accuracy and completed block entries prior to keying the form into the computer system. Corrections are made, as necessary, to the best of the DCA's ability and on the information available.

The DCA program is structured to prompt the user for completion of each data block of the form. The program tests block responses for length and character agreement with the pre-formatted block requirements. If, for example, an alphanumeric response is made to a block requiring a numeric entry, the entry will be rejected and the program will request the block entry again. In this manner, the proper type of data must be entered before the form can be accepted.

When all of the required responses have been entered and the DCA attempts to "save the data" (place the form in the DCA files), the program checks for concurrence of the entered SHIPNAME, HULL NO., and UIC with the reference files. The program must find agreement between two of the three data elements and the reference files. If errors have been made, and one or no matches are found, the the form will not be forwarded to the TSA files and an error message to the DCA will be

printed.

At any time up to the operation of the NET program by the LFA, the DCA may print out and alter his 2K entries. After NET operation, the DCA no longer has access to those entries.

A function performed by NET, while transferring the DCA entries to the TSA files, is the testing of Block 34 of the FFT reports for ETM readings. If this entry is present, the form will bypass the TSA and go directly to the LFA database files. If the entry has been omitted, the TSA will be responsible for its completion. All other types of reports automatically go into the TSA files.

3-3.2 TSA

The FRAP TSA has extensive knowledge of his assigned equipment. With this knowledge, assisted by the Reliability Model and parts lists for identifying Weapons Replaceable Assemblies (WRA) and Operational levels (O-levels), the TSA reviews the 2K information received from the DCA, applies his knowledge of the equipment and his engineering judgement to correction of the erroneous data.

At the TSA level additional block entries must be completed which are based on the failure data keyed in by the DCA.

As with the DCA program, the TSA program tests the completed form for specific data items. The type of entry in blocks 103 (COMPLETED/DEFERRAL), 106 (TYPE OF REPORT), 107 (TYPE OF NON-FAILURE REPORT), 17 (WHEN DISCOVERED DATA), 31 (COMPLETION DATA), and 102 (DATA KEYED BY DCA) are checked for entry and consistency. If the data is incorrect or missing from these blocks, an error prompt to the TSA will be printed.

The TSA program allows the TSA to access the coded 2K entry for review or re-coding. To assist in finding errors, the printout portion of the program converts the coded 2Ks back into text for easier interpretation.

3-3.3 LFA

Error detection and correction accomplished by the LFA is directed primarily toward those types of errors which are implied by a related suspicious condition. The key parameter in the FRAP evaluation is time. Specifically, this refers to the number of hours of equipment operation during the sampling period. This is reported as the Elapsed Time Meter (ETM) reading on the 2K form in Block 34 and/or in the narrative of Block 35. The ETM error detection test is a duty cycle calculation, i.e., operating hours versus calendar hours. A negative duty cycle indicates a date sequence error, while a duty cycle greater than unity indicates a value/date conflict. In both cases, engineering judgement is required to identify the source of the error and take appropriate corrective action. Since ETM corrections are difficult early in the data collection cycle, a sizeable number of such errors can be expected to show up in the database before sufficient data exists to provide accurate error detection. However, these errors are rectified by periodically re-cycling the contents of the database information through the LFA and comparing this data with the data in later entries.

The NET program scans for and flags ETM errors on 2K forms submitted to the LFA from the TSAs. These forms are re-cycled a single time to the TSAs for a solution. If that fails, the LFA determines the disposition

of the questionable 2K form. Only a small percentage of the 2Ks cannot be resolved prior to the termination of the study cycle. Using a program called CDUTY, the IFA keeps track of the problem 2Ks so that they can be corrected when sufficient information is available. A separate database file is used, specifically for maintaining undetermined reports.

3-4 RMA ANALYSES AND DATA SET SELECTION

The FRAP Pilot Program performed RMA analysis to determine Operational and Equipment parameters of the systems under study. This year an analysis to determine Parts Replacement or Logistics-demand RMA parameters has been added. The Operational analysis desribes the RMA performance of the system in Fleet operation and takes into account the system design, equipment design, operator training, maintenance training, operation/maintenance documentation effectiveness, and shipboard administrative procedures. The equipment analysis describes the RMA performance of the equipment only and provides a basis of comparison with the contractually-specified RMA performance. The Parts Replacement analysis provides a means of judging the logistics demand on the supply system and some insight into the impact upon the ship's maintenance workload of the system's RMA performance.

The same assessment procedure (described in Section IV) is used to perform all the analyses. The difference is in the criteria used to select the data to be analyzed. Data set selection criteria are as follows.

(1) OPERATIONAL RMA ANALYSIS. Failures causing a 10 percent or greater loss of system capability are selected. Active maintenance time from Block 32 of the OPNAV 4790/2K form is used for repair time calculation.

(2) EQUIPMENT RMA ANALYSIS. Failures of the equipment to perform its intended function because of hardware or software malfunction are selected. Active maintenance time from Block 32 of the OPNAV 4790/2K form is used for repair time calculation.

(3) PARTS REPLACEMENT RMA ANALYSIS. Failures requiring replacement of a part (module, circuit card, or component) are selected. Ship's Force Repair Man-hours from Block 30 of the OPNAV 4790/2K form is used for repair time calculation.

A detailed description of the data set selection process is presented in Figures 3-5 to 3-9.

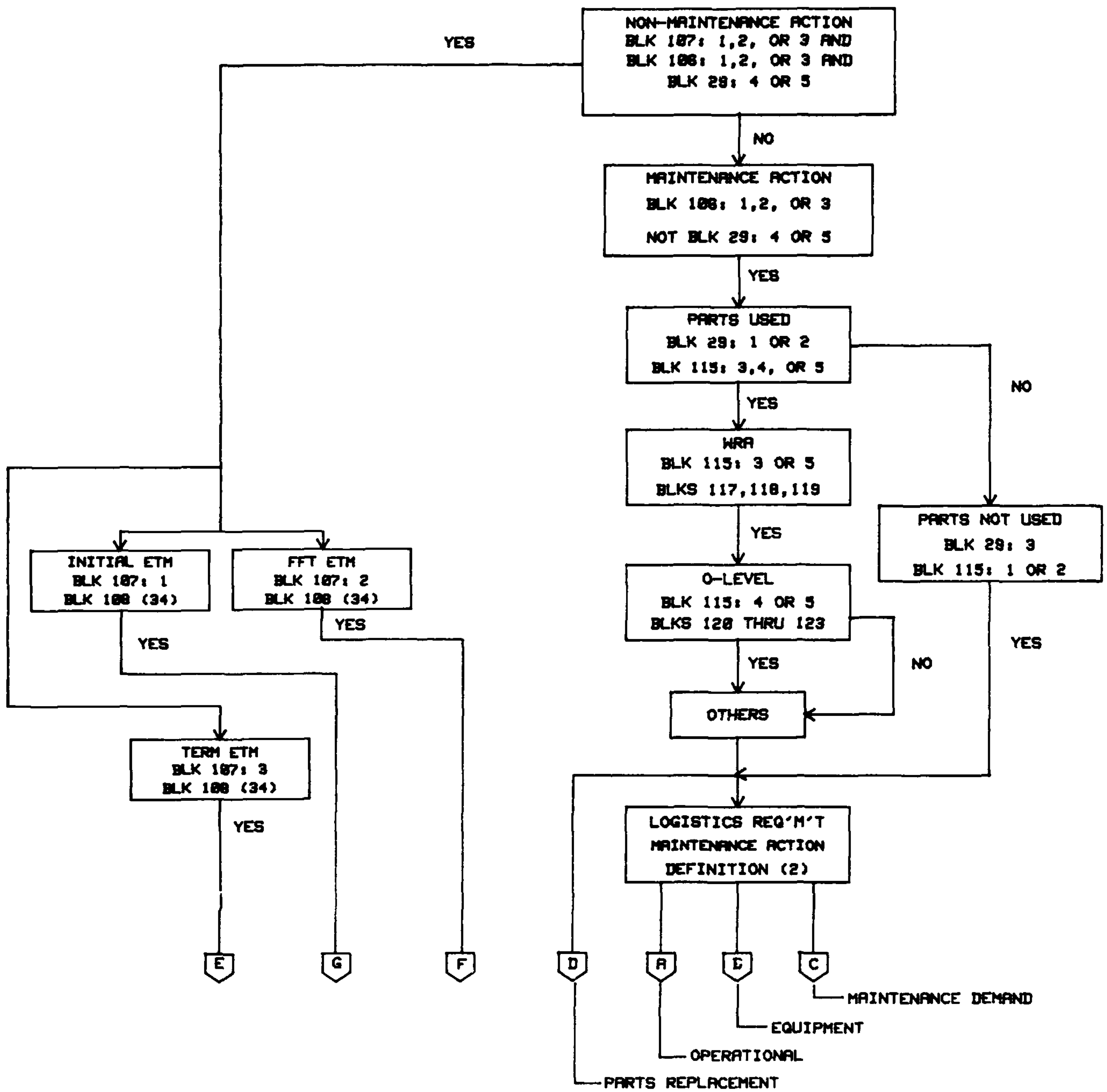

FIGURE 3-5. MATHEMATICAL ANALYSIS CHART #1

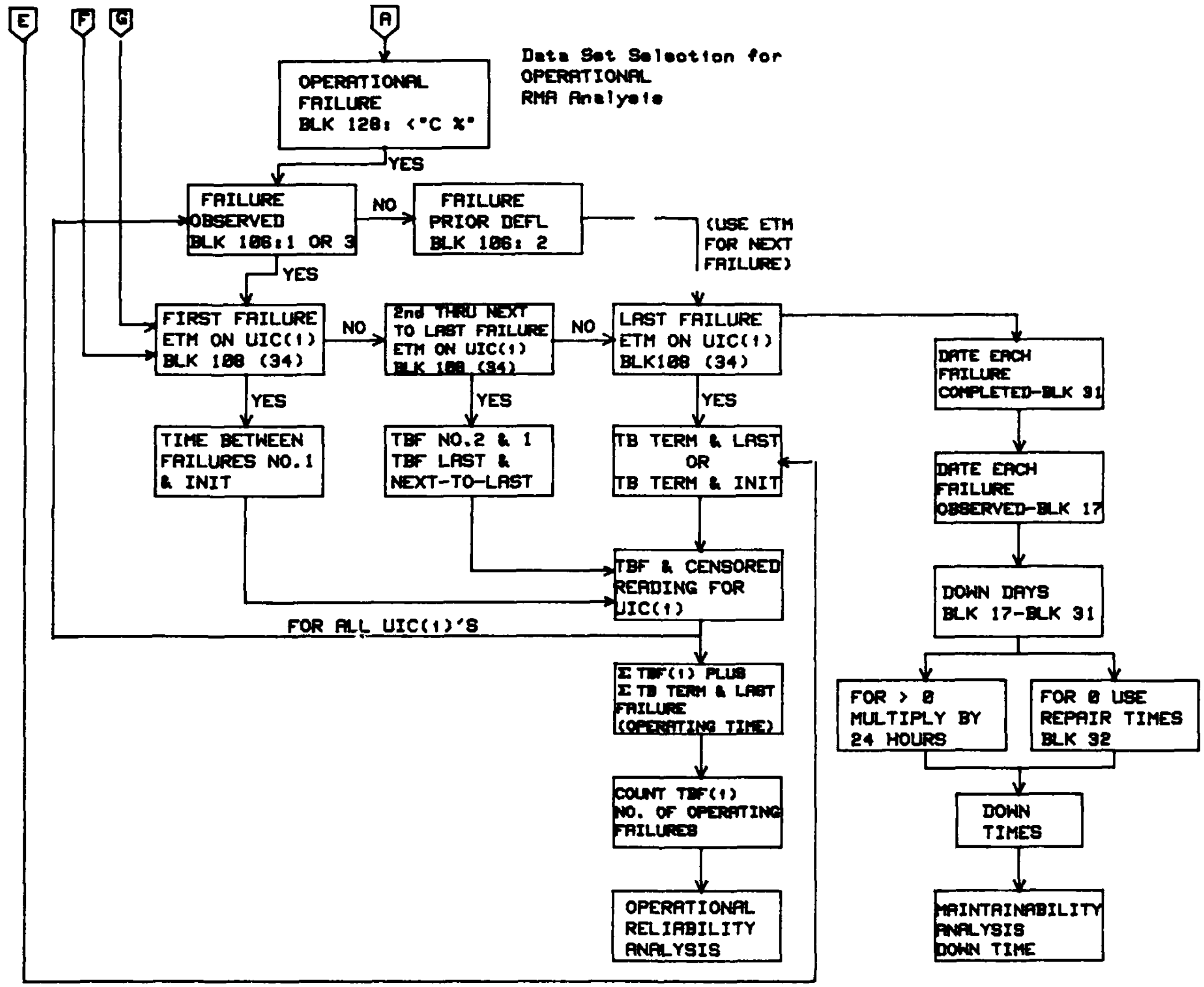

FIGURE 3-6 MATHEMATICAL ANALYSIS CHART #2

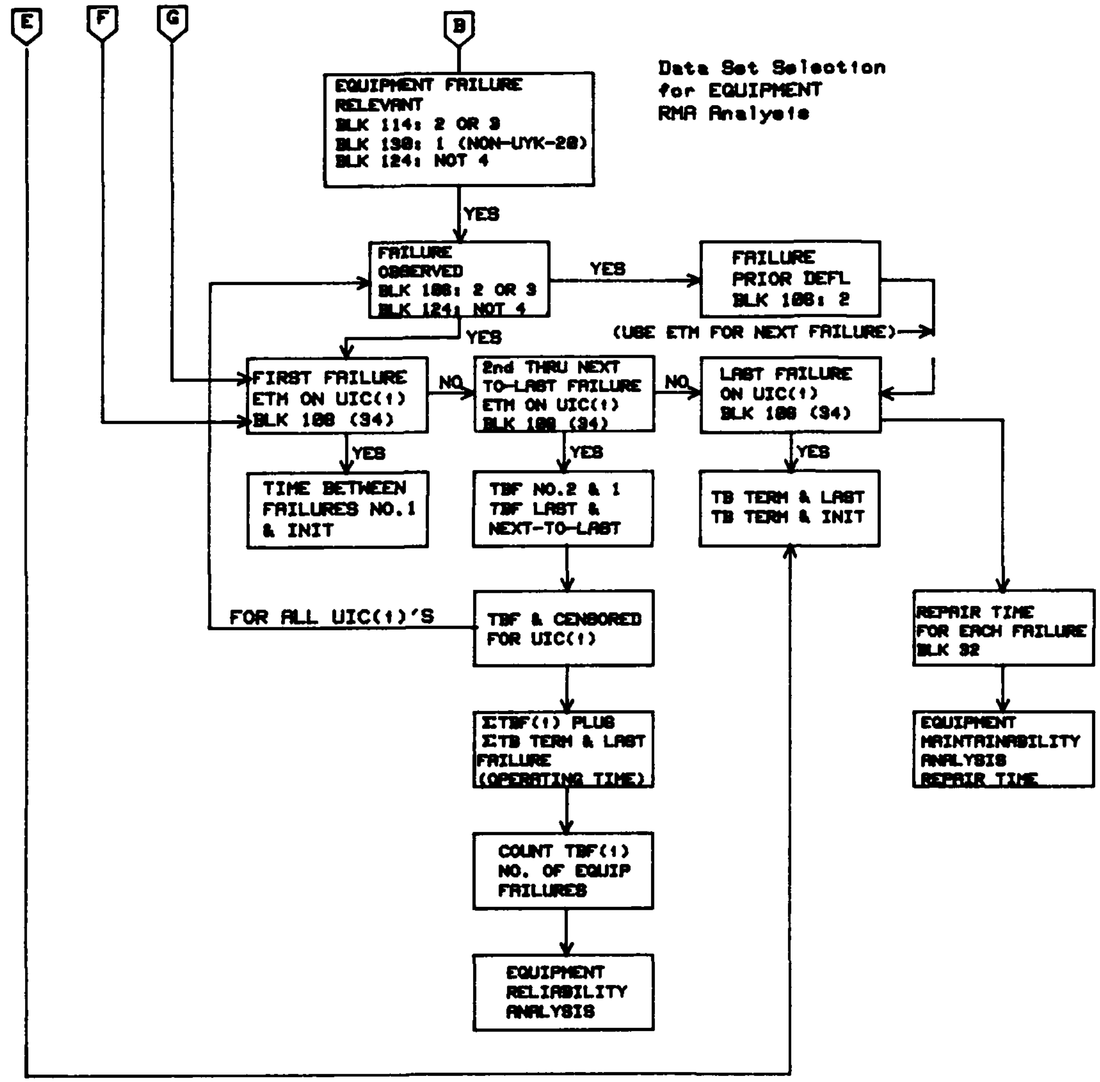

FIGURE 3-7. MATHEMATICAL ANALYSIS CHART #3

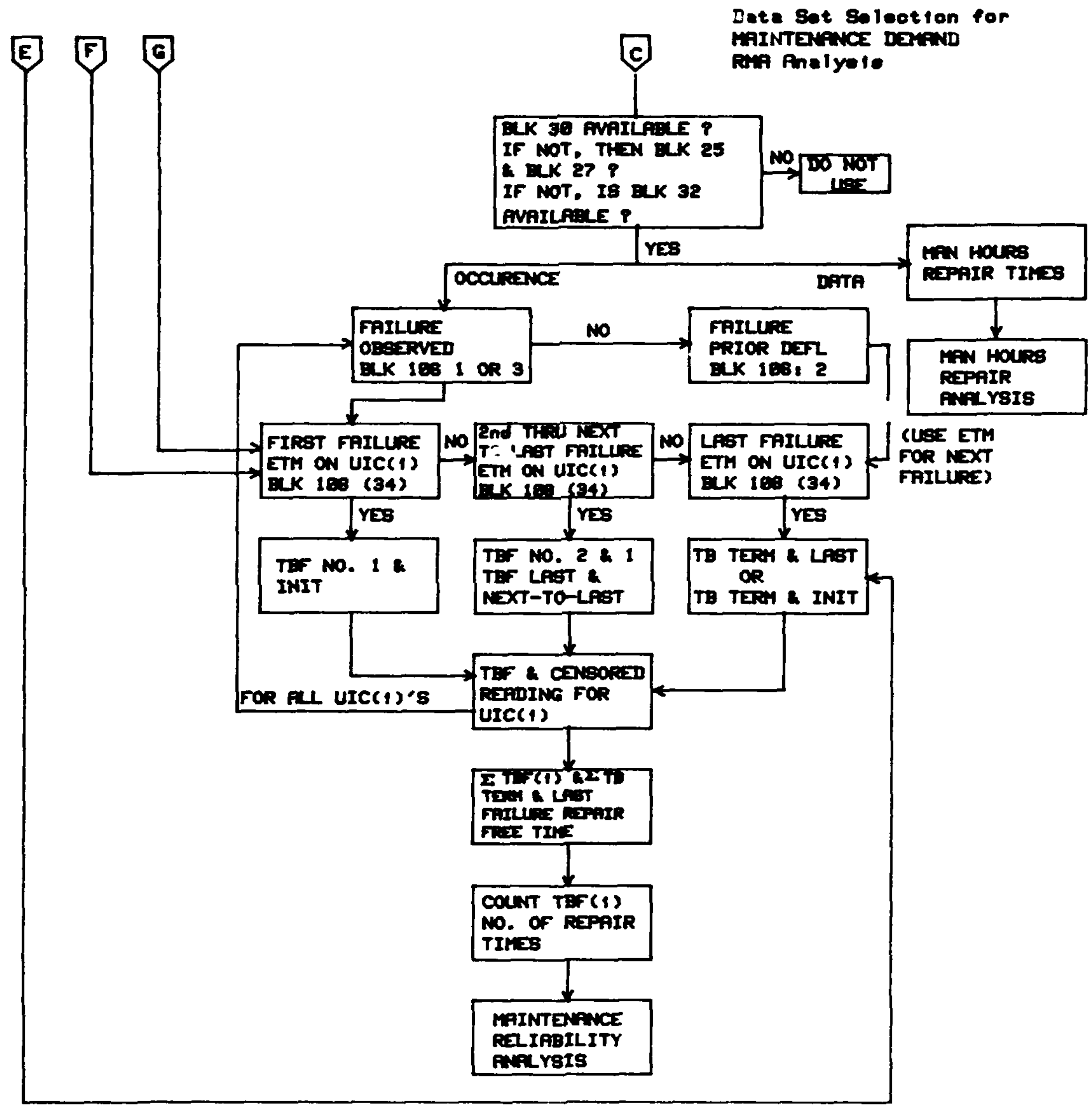

FIGURE 3-8. MATHEMATICAL ANALYSIS CHART #4

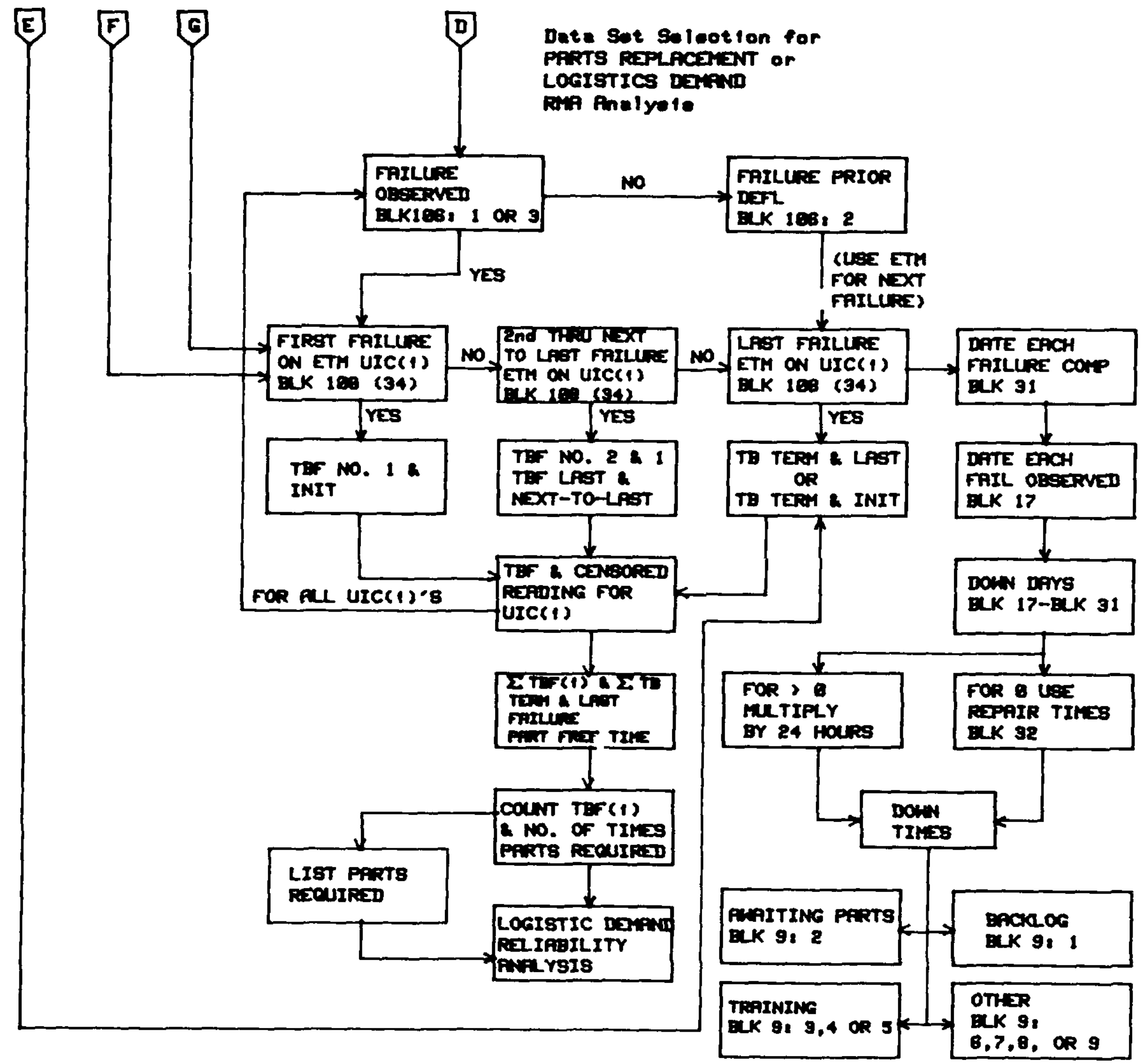

FIGURE 3-9. MATHEMATICAL ANALYSIS CHART #5

SECTION IV MATHEMATICAL ANALYSIS [ASSESSMENT PROCEDURES]

4-1 RELIABILITY ASSESSMENT

4-1.1 DATA UTILIZED

The primary data utilized in reliability assessment are Time Between Failures (TBF), Censored (C) or failure free time, WRA(s) and O-Level(s) causing failures, severity of failures (remaining system capacity), and specified or predicted (piece parts) failure rates or Mean Time Between Failures. The time between failures were obtained by finding the differences between the ETM (Elapsed Time Meter) readings at:

(a). first failure and initialization,
(b). successive failures, and
(c). termination and last failure or termination and initial reading (if no failure is observed on equipment).

4-1.2 DISTRIBUTION DETERMINATION AND PARAMETER ESTIMATION

1. Exponential vs Weibull Probability Distribution

(a). The Gnedenko F-test (references 1 and 2) is used to test the null hypothesis that the TBF's and Censored readings follow the exponential probability distribution versus the alternative hypothesis that they follow the Weibull probability distribution. The test statistic used for this is

$$Q(n_1, n_2) = \sum_{i=1}^{n_1} S_{i/n_1} \Big/ \sum_{n_1+1}^{n} S_{i/n_2} \tag{1}$$

which is distributed as the F distribution with $2n_1$ and $2n_2$ degrees of freedom. If

$$Q(n_1,n_2) > F_{\alpha/2}(2n_1,2n_2) \tag{2}$$

exponentiality is rejected and it is concluded that the failure rate is increasing (Weibull distribution should be fitted and its slope parameter, β, should be greater than one) at the $\alpha/2$ significance level. Also, if

$$1/[Q(n_1,n_2)] > F_{\alpha/2}(2n_2,2n_1) \tag{3}$$

exponentiality is rejected and it is concluded that the failure rate is decreasing (Weibull probability distribution should be fitted and β should be less than one) at $\alpha/2$ significance level.

(b). With t_i representing the i^{th} ordered failure or censored time out of n times,

$$S_i = (n-i+1)(t_i - t_{i-1}); \; t_0 = 0, \; i = 1,2---n \tag{4}$$

The n times are split into two groups: n_1 and n_2. The n_1 group consists of the first n_1 ordered times with the n_2 group consisting of the remaining $n_2 = n-n_1$ ordered times with n_1 being the largest integer less than or equal to n/2.

2. Exponential Parameter Estimation

(a). The reliability exponential probability distribution is written:

$$R(t_i) = \exp[-t_i/\theta] \tag{5}$$

where $R(t_i)$ is the probability of no failures in t_i or less operating time and θ is the parameter known as the Mean Time Between Failures (MTBF) and is estimated as follows:

$$\hat{\theta} = \sum_{i=1}^{n} [T_i BF \text{ or } TC]/r \tag{6}$$

with r being total number of failures.

(b). For the exponential distribution, the median is estimated as follows:

$$\hat{M} = \hat{\theta} \ln 2 \tag{7}$$

3. Weibull Parameter Estimation

(a). The reliability Weibull distribution may be written:

$$R(t_i) = \exp(-[\alpha t_i]^{\beta}] \tag{8}$$

where $R(t_i)$ is the probability of no failures in t_i or less operating time, and α and β are the scale and shape parameter, respectively, which are estimated using maximum likelihood equations (Reference 3). This amounts to solving the following non-linear equation for β:

$$\frac{\sum^{**} t_i^{\beta} \ln t_i}{\sum^{**} t_i^{\beta}} - 1/\beta = 1/r \sum_{i=1}^{r} \ln t_i \tag{9}$$

where

$$\sum^{**} t_i^{\beta} \ln t_i = \sum_{i=1}^{r} t_i^{\beta} \ln t_i + \sum_{i=1}^{k} C_i T_i^{\beta} \ln T_i \qquad \text{and}$$

$$\sum^{**} t_i^{\beta} = \sum_{i=1}^{r} t_i^{\beta} + \sum_{i=1}^{k} C_i T_i^{\beta} \tag{10}$$

where on the right hand end of the equations, t_i = failure time, T_i = censored time, r = total number of failures, C_i = number of censored readings at T_i, and k = number of groups of T_i. Once equation (9) is solved for β, the other parameter, α, is found as follows:

$$\hat{\alpha} = \frac{r}{\sum^{**} t_i^{\hat{\beta}}} \tag{11}$$

(b). To obtain Var $(\hat{\beta})$, the asymptotic variance - covariance matrix of $(\beta, 1/\alpha)$ is first found. Generally, this matrix is obtained by inverting the information matrix with elements that are negatives of the expected values of the second order derivatives of logarithms of the likelihood function. However, in this case, the expected values are approximated by their maximum likelihood estimates. Thus, the approximate variance-covariance matrix is:

$$\begin{vmatrix} \left.\dfrac{-\partial^2 \ln L}{\partial \beta^2}\right|_{\hat{\beta}, 1/\hat{\alpha}} & \left.\dfrac{-\partial^2 \ln L}{\partial \beta\, \partial (1/\alpha)}\right|_{\hat{\beta}, 1/\hat{\alpha}} \\ \left.\dfrac{-\partial^2 \ln L}{\partial (1/\alpha)\, \partial \beta}\right|_{\hat{\beta}, 1/\hat{\alpha}} & \left.\dfrac{\partial^2 \ln L}{-\partial (1/\alpha)^2}\right|_{\hat{\beta}, 1/\hat{\alpha}} \end{vmatrix}^{-1} = \begin{vmatrix} \mathrm{Var}(\hat{\beta}) & \mathrm{Covar}(\hat{\beta}, 1/\hat{\alpha}) \\ \mathrm{Covar}(\hat{\beta}, 1/\hat{\alpha}) & \mathrm{Var}(1/\hat{\alpha}) \end{vmatrix} \tag{12}$$

where for progressively censored samples:

$$\left.\frac{-\partial^2 \ln L}{\partial \beta^2}\right|_{\hat{\beta}, 1/\hat{\alpha}} = \frac{r}{\hat{\beta}^2} + \hat{\alpha} \sum^{**} t_i^{\hat{\beta}} (\ln t_i)^2 \tag{13}$$

$$\left.\frac{-\partial^2 \ln L}{\partial \beta\, \partial (1/\alpha)}\right|_{\hat{\beta}, 1/\hat{\alpha}} = \left.\frac{-\partial^2 \ln L}{\partial (1/\alpha)\, \partial \beta}\right|_{\hat{\beta}, 1/\hat{\alpha}} = -\hat{\alpha}^2 \sum^{**} t_i^{\hat{\beta}} \ln t_i \tag{14}$$

$$\left.\frac{-\partial^2 \ln L}{\partial(1/\alpha)}\right|_{\hat{\beta},1/\hat{\alpha}} = r\hat{\alpha}^2 + 2\hat{\alpha}^3 \sum^{**} t_i^{\hat{\beta}} \tag{15}$$

with

$$\ln L = r \ln \beta - r \ln (1/\alpha) + (\beta-1) \sum_{i=1}^{r} \ln t_i$$

$$-\alpha \sum_{i=1}^{r} t_i^{\beta} - \alpha \sum_{i=1}^{k} C_i T_i^{\beta} + \ln A \tag{16}$$

and the likelihood function

$$L = A \prod_{i=1}^{r} f(t_i) \prod_{i=1}^{k} [1-F(T_i)]^{C_i} \tag{17}$$

where A is a constant, $f(t_i)$ is the density function, and $F(T_i)$ is the distribution function. The distribution function is $1-R(T_i)$ given in equation (8). The density function is as follows:

$$f(t) = \alpha \beta t^{\beta-1} \exp(-\alpha t^{\beta}) \tag{18}$$

Per Cohen (reference 3), the foregoing variance - covariance estimation is valid in a strict sense only for large samples but may be relied upon to provide reasonable approximations to estimate variance - covariances for moderate size samples. [Although Cohen used the above density function, it is not the standard form of the two-parameter Weibull distribution in use today which is as follows:

$$f(t) = \alpha\beta(\alpha t)^{\beta-1} e^{-(\alpha t)^{\beta}} \tag{19}$$

This results in a different value of the α parameter as the α in equation 19 is the $1/\beta$ power of the α in equation 18 or as follows:

$$\alpha_{19} = (\alpha_{18})^{1/\beta} \tag{20}$$

In the computer print-out, α_{18} is used as this was used in the Pilot FRAP study.]

(c). The mean, $\hat{\mu}$, of the Weibull is estimated as follows:

$$\hat{\mu} = \hat{\alpha}^{-1/\hat{\beta}}\ \Gamma(1+1/\beta) \qquad (21)$$

where $\Gamma(1+1/\beta)$ stands for the Gamma function of $(1+1/\beta)$. The variance, σ^2, of the Weibull variates is estimated as follows:

$$\hat{\sigma}^2 = \hat{\alpha}^{-2/\hat{\beta}}\ [\Gamma(1+2/\beta) - (\Gamma(1+1/\beta))^2] \qquad (22)$$

(d). The median of the Weibull is estimated by simulation as in the FRAP pilot run. However, the median can be estimated by using the following equation:

$$\hat{M} = [\ln 2/\hat{\alpha}]^{1/\hat{\beta}} \qquad (23)$$

Application of this equation to current data shows the equation and simulation obtain similar estimates.

4. Non-parametric Function Estimation

(a). The non-parametric reliability function is obtained by arranging the failure times, t_i's, and censored times, C_i's, in ascending order and calculating for each failure time.

$$R(t_k) = \prod_{i=1}^{k} [(N_i+1-r_i)/(N_i+1)] \qquad (24)$$

where $R(t_k)$ is the probability of no failures at or before t_k, N_i is the number of failures at t_i plus the number of failures and censored time following t_i, r_i is the number of failures at t_i, and k is the last failure time in the product. (Reference 4).

5. Conversion of R(t) to F(t)

(a). For the reliability functions described above:

$$F(t_i) = 1-R(t_i) \qquad (25)$$

and is the probability of one or more failures prior to t_i.

4-1.3 CONFIDENCE LIMITS CONSTRUCTION

1. For Exponential Mean

(a). The $1-\alpha$ confidence interval or the $1-\alpha/2$ confidence limits for the mean, MTBF, of the exponential probability distribution are as follows:

$$[2T/X^2_{1-\alpha/2}(2r+2)] \leq \theta \leq [2T/X^2_{\alpha/2}(2r)] \qquad (26)$$

where T is total operating time, r is the total number of failures, and X^2 is the value of the Chi-square distribution for the given degrees of freedom, 2r+2 and 2r at the indicated percentiles $1-\alpha/2$ and $\alpha/2$, respectively.

2. For Weibull Mean

(a). The central limit theorem was applied to obtain the $1-\alpha^{th}$ confidence interval or the $1-\alpha/2$ confidence limits for the mean of the Weibull distribution as follows:

$$\hat{\mu} - t_{\alpha/2}(n-2)\hat{\sigma}/n^{1/2} \leq \mu \leq \hat{\mu} + t_{\alpha/2}(n-2)\hat{\sigma}/n^{1/2} \qquad (27)$$

where $\hat{\mu}$ and $\hat{\sigma}$ are given in equations 21 and 22, respectively, t is the value of the Student´s t-distribution with n-2 degrees of freedom at $\alpha/2$ percentile and n is the total number of observations. (Two parameters are estimated, thus n-2 degrees of freedom).

(b). In the case of small $\hat{\alpha}$ (less than .1) and/or small $\hat{\beta}$ (less than .333), these confidence limits are quite wide and thus of little value with the exception of indicating the gross uncertainty of the true value of the mean, μ. A large variation is to be expected when the β is small as the failure rate is just beginning to decrease towards a constant rate.

3. For Weibull Slope or Beta

(a). As a first estimate of confidence limits for β, the central limit theorem was again applied, thus the $1-\alpha^{th}$ confidence interval and the $1-\alpha/2$ confidence limits for the slope of the Weibull distribution is as follows:

$$\hat{\beta} - t_{\alpha/2}(n-1) - \hat{\sigma}_{\beta}/n^{1/2} \leq \beta \leq \hat{\beta} + t_{\alpha/2}(n-1)\ \hat{\sigma}/n^{1/2} \qquad (28)$$

where $\hat{\beta}$ and $\hat{\sigma}$ are as given in equations (9) and (12), respectively, and their associated equations. The primary use of this interval is to check the Weibull assumptions versus assumptions of Exponentiality (if the confidence interval includes 1, then exponential should have been assumed. Otherwise, Weibull assumption is satisfactory) and to get an awareness of distance (time) from constant failure rate (nearness of

limits to 1).

(b). The work of Mann and others is being studied for futher adaptation to computer analysis and prediction of future FRAP data (reference 5).

4-2 MAINTAINABILITY ASSESSMENT

4-2.1 DATA UTILIZED

1. The primary data utilized in maintainability assessment are repair time, down time, WRA's and O-levels being repaired or replaced, severity of failure (remaining system capacity), and specified repair times, generally Mean Time To Repair (MTTR). Repair time is defined as time required to repair equipment failures when parts, equipment, and ability for required repairs are on board the platform with the equipment. Down time is defined as the time the equipment is in a non-operational status, that being system capacity less than 90%. Down time is calculated by finding the difference between Julian date when repair was completed and Julian date when failure was observed multiplied by 24 hours if the difference is 1 or more. If the difference is zero (failure discovered and completed on the same day), repair time is used for down time.

2. Total ships manhours expended on each repair are, in some cases, given.

4-2.2 DISTRIBUTION DETERMINATION AND PARAMETER ESTIMATION

1. Lognormal vs Non-Lognormal Probability Distribution

(a). The Lilliefors Kolmogorov-Smirnov (K-S) test is used to test the null hypothesis that the time to repair (TTR) and down times (DT) follow the lognormal probability distribution versus the alternative that they do not follow the lognormal probability distribution. This essentially involves comparing the difference between the respective non-parametric maintainability functions and the estimated cumulative lognormal distribution probabilities with Lilliefors K-S test critical values.

2. Exponential vs Weibull Probability Distribution.

(a). If the lognormal distribution is rejected, the Gnedenko F-test described in paragraph 4-1.2 is used to test the null hypothesis that the repair time or down time follow the exponential probability distribution versus the alternative that they follow the Weibull probability distribution.

3. Lognormal Parameter Estimation

(a). The maintainability lognormal probability distribution is given by:

$$M(t_i) = \int_0^{z_i} [1/\sigma_z (2\pi)^{1/2}] \exp[-(z_i-\mu_z)^2/2\sigma_z^2]dz \qquad (29)$$

where $M(t)$ is the probability of completion of repair within t_i hours, z_i equals $\ln t_i$, and μ_z and σ_z equals the mean and standard deviation, respectively, of the z_i's estimated as follows:

$$\hat{\mu}_z = [\ \sum \ln t_i]/N \qquad (30)$$

$$\hat{\sigma}_z^2 = [N \sum n_i(\ln t_i)^2 - (\sum n_i \ln t_i)^2]/N(N-1) \qquad (31)$$

$$\hat{\sigma}_z = |[\sigma_z^2]^{1/2}| \qquad (32)$$

with n_i being the frequency of $\ln t_i$ and $N = \sum n_i$.

(b). These measures can then be converted to the original variable, t, as follows:

$$E(t) = \mu_t = \exp(\hat{\mu}_z + \hat{\sigma}_z^2/2) \qquad (33)$$

$$Var(t) = \sigma_t^2 = [\exp(2\hat{\mu}_z + \hat{\sigma}_z^2)][\exp(\hat{\sigma}_z^2)-1] \qquad (34)$$

(c). The median of the original observations t_i is estimated as follows:

$$\hat{M} = e^{\mu_z} \qquad (35)$$

4. Exponential Parameter Estimation

(a). The maintainability exponential probability distribution is written as:

$$M(t_i) = 1 - \exp(-t_i/\Theta) \qquad (36)$$

where $M(t_i)$ is the probability of completion of repair within t_i hours, and Θ is the exponential parameter now called Mean Time To Repair (MTTR) or Mean Down Time (MDT) and is estimated as follows:

$$\hat{\Theta} = \sum_{i=1}^{N} TTR_i/N \quad \text{(for repair time)} \qquad (37)$$

$$\hat{\Theta} = \sum_{i=1}^{N} DT_i/N \quad \text{(for down time)} \qquad (38)$$

with N being total number for each type of time.

(b). The median is estimated as shown in equation (7).

5. Weibull Parameter Estimates

(a). The maintainability Weibull probability distribution is written as:

$$M(t_i) = 1 - \exp[-\alpha t_i^{\beta}] \tag{39}$$

where $M(t_i)$ is the probability of repair within t_i hours and α and β are the scale and shape parameter, respectively, estimated as shown in equations (9), (10), and (11).

(b). The $Var(\hat{\beta})$ is estimated as described in paragraph 4-1.2(3b). Further, μ_t and σ_t are estimated using equations (21) and (22).

(c). The median is estimated as described in paragraph 4-1.2(3d).

6. Non-parametric Function Estimation

(a). The non-parametric maintainability functions are obtained by arranging the repair and down times separately in ascending order and calculating

$$M(t_k) = \sum_{i=1}^{k} n_i/N+1 \tag{40}$$

for repair times and for down times. In the above equation, $M(t_k)$ is the probability of repair completion within t_k hours, n_i is the number of observations of t_i, $\sum n_i$ is the total number of times occuring at or prior to t_i, and N is total number of times. (Reference 4)

4-2.3 CONFIDENCE LIMITS CONSTRUCTION

1. For Log-normal Mean

(a) The $1-\alpha^{th}$ confidence interval or $1-\alpha/2$ confidence limits for the mean of the log-normal distribution are given by:

$$\hat{\mu}_z - t_{\alpha/2,\, N-1}\hat{\sigma}_z/\sqrt{N-1} \leq \mu_z \leq \hat{\mu}_z + t_{\alpha/2,N-1}\hat{\sigma}_z/\sqrt{N-1} \tag{41}$$

where $\hat{\mu}_z$ and $\hat{\sigma}_z$ are as defined in equations (30), (31), and (32), t is the value of the Student's t - distribution at $\alpha/2$ percentile with N-1 degrees of freedom, and N is the total number of repair or down times.

(b) The anti-log of $\hat{\mu}_z$ and the limits construction above essentially gives the median and confidence limits on the median of the observed times, t_i.

2. For Exponential Mean

The $(1-\alpha)^{th}$ confidence interval and $(1-\alpha/2)$ confidence limits for the exponential means are:

$$[2T/X^2_{1-\alpha/2}(2N+2)] \leq \theta \leq [2T/X_{\alpha/2}(2N)] \qquad (42)$$

where T is total maintainance or repair time, N is the number of times observed, X^2 is the value of the Chi-squared distribution for the given degrees of freedom, 2N+2 and 2N, at the indicated percentiles of $1-\alpha/2$ and $\alpha/2$, respectively.

3. For Weibull Mean and Shape

(a) The maintainability confidence limits for the Weibull mean and shape are constructed as described in paragraphs 4-1.3(c2) and 4-1.3(c3), respectively.

4-3 AVAILABILITY ASSESSMENT

4-3.1 INHERENT AVAILABILITY

Inherent availability is defined as the average time an equipment is available assuming its only down time is repair time and thus is given by:

$$A_I = MTBF/(MTBF + MTTR) \qquad (43)$$

The estimates of MTBF and MTTR obtained as described in paragraphs 4-1 and 4-2 are used in the above equation.

4-3.2 OPERATIONAL AVAILABILITY

Operational availability is defined as the ratio of time between failures (TBF) to sum of the TBF and Down Time (DT) for each maintenance action (reference 8) which is expressed as follows:

$$A_{oi} = TBF_i/(TBF_i + DT_i) \qquad (44)$$

The A_{oi}'s are calculated for each failure with a down time. Then, these are arranged in an ascending order and the cumulative function:

$$P(A_{ok}) = \sum_{i=1}^{k} n_i/N \qquad (45)$$

is calculated. Here $P(A_{ok})$ is the proportion of availabilities equal to or less than A_{ok}, n_i is the number of availabilities with the A_{oi} value,

$\sum n_i$ is the number of observed availabilities equal to or less than A_{ok}, and N is the total number of observed availabilities.

The mean, median, and confidence limits for A_{oi} are estimated using simulation methods. The probability distributions and estimated parameters

obtained in paragraph 4-1 and 4-2 are used in the simulation of ratios described in equation (44). The formulae used to generate these values are as follows (reference 9):

(a) Exponential

$$TBF_i \text{ or } DT_i = -\hat{\theta} \ln (1-R_{v_i}) \quad (46)$$

where $\hat{\theta}$ is the estimated MTBF or Mean Down Time (MDT) and R_{v_i} is a random variable from a uniform distribution over the interval (0,1).

(b) Log-normal

$$TBF_i \text{ or } DT_i = \exp(\hat{\sigma} R_{n_i} + \hat{\mu}) \quad (47)$$

where $\hat{\mu}$ and $\hat{\sigma}$ are the estimated mean and standard deviation of the logarithms (equations (30) and (31) and R_{n_i} is a random value from the normal distribution with $\mu = 0$ and $\sigma = 1$.

(c) Weibull

$$TBF_i \text{ or } DT_i = [-\ln (1-R_{v_i})/\hat{\alpha}]^{1/\hat{\beta}} \quad (48)$$

when $\hat{\alpha}$ and $\hat{\beta}$ are obtained as described under Weibull estimates in paragraph 4-1.2(3) and 4-2.2(5)

(d) As a TBF_i and DT_i is generated, an A_{oi} is calculated. After 2000 A_{oi}'s are calculated, the mean and median of these values are obtained. The mean is simply the arithmetic mean of these 2000 A_{oi}'s. However, the median is the average of the values for which 999 of the A_{oi}'s are greater and 999 are less.

(e) The $(1-\alpha)^{th}$ confidence interval or the $(1-\alpha/2)$ confidence limits for individual ratios are obtained by determining the A_{oi} value for which 10% of the simulated A_{oi}'s are less and the value for which 10% are greater.

4-3.3 EFFECTIVE AVAILABILITY

Effective Availability accounts for the varying degree of capability loss in a complex (redundant) system. It is calculated as follows:

$$A_{eff} = (\sum TBF_i /(\sum TBF_i + [\text{Mean Capability Loss}] \sum DT_i) \quad (49)$$

SECTION V MATHEMATICAL ANALYSIS (OUTPUT DESCRIPTION)

5-1 RELIABILITY ASSESSMENT

5-1.1 FLEET RELIABILITY ASSESSMENT DATA

1. Source

(a). The OPNAV 4790/2K form is FRAP's basic raw reliability data. The data are derived from four types of fleet submittals. The first type of submittal is an initialization report at the beginning of the observation period for the FRAP assigned equipment. The fourth and last type is a final or termination report at the end of the FRAP assigned equipment observation period. In between these there are maintenance action and failure free type of reports. A maintenance action report is submitted whenever there is a need for a non-preventive maintenance action, thus generally in case of a failure. Failure free reports, also known as censored, are submitted for failure free periods. Maintenance action reports are sub-divided into those deferred for outside assistance and those completed by ship's personnel without deferral.

2. Output Description

(a). For each submittal the following are given: Name of FRAP assigned system, Name of ships having one of the FRAP samples, Julian date, Elapsed Time Meter (ETM) reading, Failure (report) type, Operating time, Failure (and censored) times, Duty Cycle, WRA failing, O-level failing in order of cause of failure. The Julian date is the date of the ETM reading which for a failure or deferred failure is the date need for maintenance action was discovered. The ETM reading and failure type is as indicated. Operating time is the cumulative equipment on time since the initial report was submitted. Then in the failure time column, time between failures and time to censor is given for censored and final submittals. The cumulative duty cycle is given in the duty cycle column. Duty cycle is defined as the difference between ETM readings divided by the difference between the respective Julian dates multiplied by 24 hours per day. It is noted that for initial, censored, and final submittals, no failures are generally encountered. This is shown by zeros in the WRA and O-level columns for the submittals.

5-1.2 RELIABILITY (SYSTEM LEVEL)

1. Source

(a). The source of the basic data (time to fail and time to censor) is the failure time column of the Fleet Reliability Assessment Data discussed above.

2. Output Description

(a). The remaining system capacity indicates the severity of the failure with respect to system mission. Then the time to fail column consists of the above mentioned failure and censored times arranged in

ascending order. The following two columns indicates whether these readings are failures or censored times. This is followed by the survivors column which indicates the number of failure and censored readings equal to or greater than the listed failure times. This is then followed by the non-parametric estimated probabilities (See paragraph 4-1.2(4). These are followed by the theoretical exponential estimated probabilities (See paragraph 4-1.2(2) which are followed by the theoretical Weibull estimated probabilities (See paragraph 4-1.2(3). All of these probabilities are the "probability of a system having one or more failures at or prior to the listed failure time".

(b). In the narrative block style presentation after the above columnar presentation, the following are given:

(1) Total equipment operating hours,
(2) Total calendar hours (sum of differences between Final and Initial submittals; Julian dates multiplied by 24 hours),
(3) Overall duty cycle,
(4) Number of systems,
(5) Observed system failure rate per operating hours (number of failures divided by operating hours),
(6) Gnedenko Q ratio for testing null hypothesis that exponential distribution exists versus the alternative of a Weibull distribution (See paragraph 3-4.1.1b1),
(7) Estimated mean with assumed distribution,
(8) Estimated median with assumed distribution,
(9) 90% Lower Confidence Limit (LCL) for mean of assumed distribution,
(10) 90% Upper Confidence Limit (UCL) for mean of assumed distribution,
(11) 90% LCL for β if the Weibull distribution is assumed,
(12) 90% UCL for β if the Weibull distribution is assumed,
(13) a statement if the system meets specifications (i.e. specified value below UCL).

(c). In case of 4 or less failures, the exponential probability distribution is assumed.

5-1.3 RELIABILITY (WRA LEVEL-for each WRA)

1. Source

(a). The source of the basic data (time between failures and time to censor) is a WRA failure and censored time column (not printed) obtained by considering WRA failures with respect to system operating time.

2. Output Distribution

(a). The output is the same as described in paragraph 5-1.2(2) but is for a WRA on a system level basis. System level means that the time between failures and censored times are for WRA types, for example, WRA 14's or power supplies within a system and not for a specific WRA 14. Accordingly, the specification is also converted to a WRA system

basis.

5-1.4 RELIABILITY O-LEVEL SUMMARY

1. Source

(a). The sources of this data are the reliability block diagram, system operating times, WRA failures, and O-level failures.

2. Output Description

(a). For each O-level failing, the folowing is presented:

(1). Reliability block diagram number for WRA failing,

(2). O-level block diagram number and nomenclature for O-level failing,

(3). Number of O-levels failing,

(4) The 90% lower confidence limit for the estimated exponential mean (exponentiality is a[illegible]umed for all O-levels due to the expected small number of failures),

(5). The estimated exponential mean, and,

(6) the upper 90% confidence limit, and also

(7) The specified O-level Mean or MTBF is obtained using piece-parts (MIL-HDBK-217) predictions. (In case of multiple number of the same O-level, failure rates are added and then reciprocal obtained for the specified MTBF.),

(8) Followed by the O-level component's low and high observed failure times,

(9) Ending with whether a reliability problem exists or not. A reliability problem exists if the upper confidence limit is less than the specified MTBF.

5-1.1 RELIABILITY 2K SUMMARY FOR PROBLEM AREAS

1. Source

(a). The above O-level output and 2K data file.

2. Output Description

(b). For those O-levels for which a reliability problem exists, the following is given for the 2K forms pertaining to those failures:

(1). Job Control Number (JCN),

(2). Primary WRA failing, and

(3). O-level failing in order of importance with respect to cause of failure.

(4). Short description of what happened.

5-1.6 Graphs

1. Source

(a). Reliability System Level, and

(b). Reliability WRA Level Outputs

2. Description of Output

(a). For the system and each WRA with four or more failures, one or two graphs of system operating time versus probability of failure (one or more failures) is (are) presented. On each graph the non-parametric probabilities are plotted as a step function. A graph is always presented illustrating the exponential probabilities versus the non-parametric probabilities. Then if the Weibull distribution is chosen, a graph is given illustrating the estimated Weibull probabilities versus the non-parametric probabilities. Additionally, on each graph the estimated mean and median for the assumed distribution is printed.

5-2 MAINTAINABILITY ASSESSMENT

5-2.1 FLEET MAINTAINABILITY ASSESSMENT DATA

1. Source

(a). This essentially is FRAP's raw maintainability data. These data are essentially derived from one type of Fleet submittal, which is the completed maintenance action reports.

2. Output Description

(a). For each completed maintenance action report, the following are given: Name of FRAP assigned system, name of ships having one of the FRAP sample, Julian date needed for maintenance action discovered, Julian date maintenance completed, repair time (hours required to repair equipment), and system down time (Julian completion date minus Julian discovered date multiplied by 24 hours per day).

5-2.2 MAINTAINABILITY (DOWN TIME) SYSTEM LEVEL

1. Source

(a). The source of the basic data (down time) is the down time column of the Fleet Maintainability Assessment Data output discussed in paragraph 5-2.1 above.

2. Output Description

(a). The down time column consists of the above mentioned down time arranged in ascending order. This is followed by the frequency of the down time and then the cumulative frequency which gives the number of down times equal to or less than the listed down time. This is then followed by the non-parametric function probabilities (See paragraph 4-2.2(6). These are followed by the theoretical log-normal estimated probabilities (see paragraph 4-2.2(3) which are followed by the theoretical exponential estimated probabilities (see paragrapn 4-2.2(4) which are followed by the theoretical Weibull estimated probabilities (see paragraph 4-2.2(5). All of these probabilities are the "probability of a system being up within the given down time".

(b). In the narrative block style presentation after the above described columnar presentation, the following are given:

(1). Total down time,

(2). Number of repairs,

(3). Mean of observed down time (number of down time hours divided by number of repairs),

(4). Standard Mean and Deviation of natural logarithms of down time,

(5). Lilliefors K-S test results for log-normality assumption,

(6). If log-normality can not be assumed, results of the Gnedenko Q-test for testing null hypothesis that the exponential distribution exists versus the alternative of a Weibull distribution (see paragraph 4-2.2(2) and 4-1.2(1) are given,

(7). Estimated Mean with assumed Distribution, ($\hat{\alpha}$ and $\hat{\beta}$ are also given for the Weibull),

(8). Estimated Median with assumed Distribution,

(9). 90% Lower Confidence Limit (LCL), for Mean of assumed distribution,

(10). 90% Upper Confidence Limit (UCL) for Mean of assumed distribution,

(11). 90% LCL for β if the Weibull is assumed,

(12). 90% UCL for β if the Weibull is assumed.

5-2.3 MAINTAINABILITY (REPAIR TIME) SYSTEM LEVEL

1. Source

(a). The source of the basic data - repair time - is the repair

time column of the Fleet Maintainability Assessment Data output described in paragraph 5-2.1.

2. Output Description

(a). This is very similar to the Maintainability (Down Time) System Level Output described in paragraph 5-2.1(2) with the following exceptions:

(1). Repair Time is the basic variable,

(2). Total Repair Time instead of Total Down Time is given,

(3). Observed repair rate (total number of repair hours divided by number of repairs) instead of mean down time is given,

(4). At the end of a statement is given whether the equipment meets specifications (i.e., specified value greater than the LCL .

5-2.4 MAINTAINABILITY (REPAIR TIME) WRA LEVEL (EACH WRA)

1. Source

(a). The source of the basic data time to repair WRA, is the repair time column of the Fleet Maintainability Assessment Data (see paragraph 5-2.1(2a) but only for those repairs concerned with the respective WRA´s.

2. Output Description

(a). The output is the same as described in paragraph 5-2.3(2) above but is for the WRA instead of the system.

5-2.5 MAINTAINABILITY (REPAIR TIME) O-LEVEL SUMMARY

1. Source

(a). The sources of those data are the reliability block diagram and the repair time column of the Fleet Maintainability Assessment Data (see paragraph 5-2 but only for those repairs concerned with the listed O-levels.

2. Output Description

(a). For each O-level failing and for which repair time exists, the following is presented:

(1). Reliability diagram block number for WRA being repaired.

(2). O-level reliability diagram block number and nomenclature for O-levels being repaired.

(3). Number of times O-level repaired and for which repair time exists.

(4). The 90% Lower Confidence Limit for the estimated log-normal mean in terms of repair times (log-normality is assumed for all O-levels due to the expected small number of repairs).

(5). The 90% Upper Confidence Limit for the estimated log-normal mean.

(6). Specified Mean Time To Repair (MTTR).

(7). The mean of the observed repair times with the low and high observed repair time, and

(8). Whether a maintainability problem exists or not. A maintainability problem exists (if specified value greater than LCL).

5-2.6 MAINTAINABILITY (REPAIR TIME) 2K SUMMARY FOR PROBLEM AREAS

1. Source

(a). The above O-level maintainability output and 2K failure description file.

2. Output Description

(a). For those components for which a maintainability problem exists, a summary for the related 2K's is given consisting of:

(1). Job Control Number (JCN)

(2). Primary WRA failing

(3). O-level's failing in order of importance with respect to primary O-level failing, and

(4). Short description of problem.

5-2.7 Graphs

1. Source

(a). Maintainability (down time) system level output,

(b). Maintainability (repair time) system level output, and

(c). Maintainability (repair time) WRA level (each WRA) output

2. Output Description

(a). Graphs are produced for system down time and system repair times. Graphs are also presented for WRA repair times (if four or less repair or down times exist, no graphs are developed). These graphs present down time or repair time versus the probability of repair completion within these times. On each graph the non-parametric

maintainability (cumulation observed) probabilities are presented as a step function. A graph is always presented illustrating the estimated log-normal probabilities versus the step function probabilities. Then if the log-normal distribution is not assumed, a graph is produced illustrating the estimated exponential probabilities versus those of the step function. Further, if the exponential can not be assumed, a final graph showing the estimated Weibull probabilities versus the step function is obtained. The estimated mean and median of the assumed distribution is given on each graph.

5-3 AVAILABILITY ASSESSMENT

5-3.1 Inherent Availability

1. Source

(a). System Reliability Assumed Distribution and Estimated Parameters (paragraph 5-1.2(2b), and

(b). System Maintainability (repair time) assumed distribution and estimated parameters (paragraph 5-2.3(2a).

2. Output Description

(a). System mean failure time,

(b). System mean repair time,

(c). Inherent Availability (Mean failure time divided by Sum of Mean Failure Time and Mean Repair Time).

5-3.2 OPERATIONAL AVAILABILITIES

1. Source

(a).System Reliability Assumed Distribution and Estimated Parameters (paragraph 5-1.2(2b),

(b). System Maintainability (down time) assumed distribution and estimated parameters (paragraph 5-2.2(2b), and

(c). 2000 simulations of TTF/[TTF + DT] ratio.

2. Output Description

(a). Estimated Mean of availabilities of equipment in a fleet environment,

(b). Estimated median of above availabilities,

(c). 90% Lower Confidence Limit (LCL) for an equipment availability,

(d). 90% Upper Confidence Limit for an equipment availability

(e). Graph presenting cumulative observed distribution (ratio for each failure) versus simulated operational availability distribution.

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SECTION VI REPORTS

Users of the FRAP database network reporting capability are provided a high degree of variety and flexibility in obtaining reports containing specific user selected elements. The repositories for the reporting function are referred to as QUERY and FRAP. As shown in Figure 3-2, QUERY and FRAP are essentially parallel and receive the same processed information. However, QUERY allows users to access the preliminary data available in the DCA and TSA files. The primary advantage of this "quick-look" feature is the early detection of equipment problem trends, thus alerting the FRAP team to monitor specific equipment types which appear especially troublesome. Futhermore, missing 2K data or improper entries can be detected and appropriate action taken before valuable maintenance information is lost. The redundancy of the databases prevents the loss of the FRAP data should either of the databases "crash", i.e., be destroyed inadvertently through either personnel error or hardware/software failure. The system is structured such that either database can be re-loaded from the other. Access to raw data from the Fleet, as well as general information of interest, and preliminary reliability calculations are available via QUERY almost as soon as it is received. The types of reports available from the QUERY database are shown in Table 6-1.

At about one month intervals during the sampling period, the contents of each database are correlated with the previous month's maintenance data to remove erroneous or redundant data. When sufficient data has accumulated, a statistical analysis is performed and the results then become available under FRAP. Table 6-2 illustrates the types of reports which can be accessed from the FRAP database.

TABLE 6-1. *QUERY DATABASE REPORTS*

TYPE OF REPORT	DESCRIPTION
SEARCH(Shipname)	A brief report of report type, equipment type, and 2K serial numbers for the designated ship.
REPORT(Option No.)	Provides reports based on user option of (1) 2Ks received per ship and equipment; (2) total 2Ks received per ship and the report type; (3) same as (2) with serial numbers added; (4) same as(2) with WHEN DISCOVERED DATE added; (5) same as (2) with TYCOM CODE added; (6) Preliminary Reliability Report.
PRINT(Option)	Provides a printout of the

	complete 2K form (or any part of it) as selected by serial number.
SHIPLIST	Provides a listing of ships participating in FRAP and includes HULL NUMBERS, UICs, and TYCOM CODES.
UPDATE	Reports the number of 2Ks placed on file during a user specified time frame of the sampling period. A summary listing of the forms is provided as a user option.
DATALIST	Provides a listing of DCA or TSA data blocks and block description according to user selection.
FREE-FORM	Allows creation of a report based on user selected 2K block numbers, sort sequence, and selection criteria.

TABLE 6-2. FRAP DATABASE REPORTS

RELIABILITY(n)	Provides a reliability report of equipment type n.
MAINTAINABILITY(n)	Provides a maintainability report for equipment type n, including maintenance time and status.
SEARCH(n)	Generates a report of problems as user selected by equipment type number n.
TEXT(n)(Shipname)	Reports equipment failures and what happened by equipment type n and by name of ship.
2K-STATUS	Reports the quantity of 2Ks received per ship and per equipment and the totals.

SECTION VII FUTURE PLANS

7-1 DEPOT DATA COLLECTION

As in the pilot phase, it is anticipated that in future FRAP samples data provided by the Depot repair facilities will contribute significantly to the effort of identifying specific equipment problems. With this source of data, FRAP plans to establish as an integral function of the present collection and analysis network, operations which will include the Depot data and will provide a database dedicated to the storage of the Depot maintenance information. The planned database will allow access and reporting to FRAP participants as does the QUERY and FRAP databases.

7-2 SOFTWARE FAILURE REPORTING

Weapons systems development over the past few years has leaned heavily in favor of including mini- and microcomputers as key elements within the system designs. However, while the hardware components have trended toward higher reliability, system software problems are representing a larger percentage of the total population of equipment problems.

At present, there are no known software surveillance programs whose purpose is to detect and rectify current and future software system failures.

In the near future, FRAP plans to study the feasibility of incorporating software failure reports into the data collection system as an integral part of the equipment reliability studies.

GLOSSARY
OF
ACRONYMS AND TERMINOLOGY

TERM	DEFINITON
ASCII	American Standard Code for Information Interchange.
CASREPT	Casualty Report
CATCC-DAIR	Carrier Air Traffic Control Center-Direct Altitude and Identity Readout
CDC	Control Data Corporation
CENSORED (time)	Failure Free (time)
COMP	Completed Maintenance Action
CONUS	Continental United States
CO-VARIANCE	The expected value of the product of two random variables, each offset by their mean.
DCA	1. Data Collection Activity (or Agent) 2. Computer Program used by the Data Collection Activity to enter OPNAV 4790/2K Maintenance Action Information
DEFL	Deferred Maintenance Action
DT	Down Time
ECP	Engineering Change Proposal
EIC	Equipment Identification Number
ETM	Elapsed Time Meter
FFT	Failure Free Time
FFTR	Failure Free Time Report (Censored)
FMA	Fleet Maintenance Agent
FMSO	Fleet Material Support Office
FRAA	Fleet Repairables Assistance Agent
FRAP	1. Fleet Reliability Assessment Program 2. Name of a computer program that permits retrieval of FRAP data from SYSTEM 2000 Database.

INIT	Initialization Report
JCN	Job Control Number
JULIAN DATE	A measure of calendar time consisting of four (4) digits, where the first digit is the last digit of the year and the remaining three digits index the day of the year from 001 for 1 January to 365 for 31 December.
LCL	Lower Confidence Level
LFA	Lead Field Activity
MDT	Mean Down Time
MEAN	The expected value or arithmetic average, also called the first moment of the statistical distribution about the origin.
MEDIAN	The 50^{th} percentile of a distribution.
MOTU	Mobile Training Unit
MTBF	Mean Time Between Failure
MTTR	Mean Time To Repair
NAVMACS	Naval Modular Automated Communications System
NET	A computer program used to transfer the OPNAV 4790/2K Maintenance Action Information from function to function within the FRAP data collection network
NPD	Non-Parametric Distribution
O-Level	Operational Level of Maintenance
OPNAV 4790/2K MAF	A standard maintenance action form used by 3-M for the reporting of shipboard maintenance actions and for the additional FRAP reporting requirements of Initialization, Failure Free Time and Terminations. (Also 4790/2K or 2K)
PMF	Project Management Office in NAVELEXSYSCOM
QUERY	A computer program used to access the total FRAP database
RAM	Reliability, Availability, Maintainability, or

	Reliability and Maintainability
RMA	Reliability, Maintainability, Availability
SPCC	Ships Parts Control Center
SYSTEM 2000	Name of a general purpose database management system in the Control Data Corporation CYBERNET system (Also SYSTEM 2k)
TBF	Time Between Failure
TERM	Termination Report
TSA	1. Technical Support Activity (or Agent) 2. A computer program used by the TSA to process DCA entered OPNAV 4790/2K MAFs
TTR	Time To Repair
UCL	Upper Confidence Level
UIC	Unit Identification Code (for a ship)
VARIANCE	The second moment about the expected value.
WRA	Weapons Replaceable Assembly


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8